18th CONGRESS,
2d SESSION.

MESSAGE

FROM THE

PRESIDENT OF THE UNITED STATES,

TRANSMITTING

A Report of the Commissioners

APPOINTED UNDER THE ACT OF THE THIRD OF MARCH, 1823,

TO ESTABLISH

A National Armory

ON

THE WESTERN WATERS.

JANUARY 18, 1825.

Read: ordered that it be laid upon the table.

WASHINGTON:

PRINTED BY GALES & SEATON.

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WASHINGTON, *January* 18, 1825.

To the House of Representatives of the United States:

I herewith transmit to the House of Representatives a report of the Secretary of War, with a report made to that Department by the Commissioners who were appointed under the act of 3d March, 1823, entitled "An act to establish an Armory on the Western Waters."

JAMES MONROE.

DEPARTMENT OF WAR,

January 17th, 1825.

SIR: I transmit, herewith, a report of the Commissioners appointed under the act of the 3d of March, 1823, entitled "An act to establish a National Armory on the Western Waters."

The Commissioners appointed under the abovementioned act, were Colonels William M'Ree, Roswell Lee, and Major George Talcott, who proceeded to execute its provisions, under the instructions of this Department, of which the enclosed papers, marked A and B, are copies.

The delay which has occured in making their report, will be fully seen by reference to the report itself.

I have the honor to be,
Your obedient servant,

J. C. CALHOUN.

The PRESIDENT *of the United States.*

A.

War Department,

Washington, 26th April, 1823.

Sir: The President has been pleased to appoint you to perform the duties required by "An act to establish a National Armory on the Western Waters," a copy of which act is herewith enclosed. The President has, also, appointed Lieutenant Colonel Roswell Lee, Superintendent of the United States Armory at Springfield, and Captain George Talcott, on Ordnance duty at the United States Arsenal at Pittsburg, to be associated with you on this service. Upon your acceptance of this appointment, you will please to notify Lieutenant Col. Lee and Captain Talcot, of the time and place at which you may think it advisable to assemble, preparatory to entering upon the duties pointed out by the act.

In order that the intention of the act may be fulfilled in the most ample manner, and all objections which may be urged in favor of other sites be met, so as to ensure the adoption of the one which may be recommended, it is considered proper that all the sites on the "Western Waters," of which you may be informed, and of the suitableness of which any reasonable expectations may be entertained, should be examined. It is considered necessary, also, that the report of these examinations should contain a notice of each of the sites examined, and exhibit the opinions of the Board, respecting the suitableness of each, respectively, and the facts and reasons upon which those opinions are formed.

The districts of country which your examinations should embrace, and to which they should be limited, under the term "Western Waters," is submitted to the judgment of yourself and associates; it is considered, however, that the examinations should be extended, at least, to all the sites upon the Ohio river, or upon any of its tributaries.

I transmit, herewith, a communication from the Ordnance Department, exhibiting its views respecting the situation of a site for an Armory, which is submitted for your consideration. Any information which has been, or may be received, pointing out the position of any sites deemed suitable for an Armory, will be communicated to you by the Ordnance Department.

Your compensation, while in the discharge of the duties of this appointment, will be eight dollars per diem, and an allowance for travelling expenses equal to that allowed to a Colonel of the army. The per diem will commence at the date of your acceptance of this appointment, and will continue until your duties under it shall cease. The compensation of Lieutenant Colonel Lee, and Captain Talcott, will be two dollars per diem, and the travelling allowance due to their respective stations in the public service, in addition to the compensation

which they now receive. The per diem to commence at the time of their commencing their duties under this appointment, and to continue as long as they may be engaged upon these duties.

Respectfully, I am, sir,
Your most obedient,
J. C. CALHOUN.

Col. WILLIAM M'REE,
Wheeling, Virginia.

B.

ORDNANCE DEPARTMENT,

24th April, 1823.

SIR: The "Act to establish a National Armory on the Western Waters," does not specify the scale or extent of the Armory for which a site is to be selected. A resolution of the Senate, calling for information respecting a Western Armory, required an estimate "of the cost of erecting, on the western waters, such an armory as that at Springfield or Harper's Ferry." From the terms of this resolution, and of the report made in obedience thereto, both of which preceded, and, in some degree, led to, the passage of the act above mentioned, it is, therefore, infered, that Congress contemplated the selection of such a site as would be suitable for an armory of equal extent to those already established. It is, therefore, conceived, that the officers charged with the examination of the various sites, should be instructed to examine all such as may be supposed to be suitable for an armory upon a similar scale to those above mentioned, viz: An armory properly adapted for the fabrication of twelve thousand muskets per annum. This, it is conceived, should be the minimum, but it would be desirable to possess such a site as would admit of an enlargement of the establishment hereafter, if the public interest should render it necessary.

The principal points deemed most worthy of consideration in the location of an armory, may be briefly enumerated as follows, viz:

First—A sufficient power for driving all the necessary machinery. This should be constant, and at command, and not liable, either to be obstructed by floods, nor to fail by droughts. These are most essential conditions, and no site can be suitable when the moving power is uncertain, or liable to failure from any ordinary cause. The question, whether steam power may not be advantageously employed as a substitute for water power, to a certain extent, is deemed worthy the consideration of those who will examine the sites.

Second—A healthy position, and one where subsistence may be cheaply obtained. These points are important, inasmuch as the price of labor at the establishment must, ultimately, in a great measure, be determined by them.

Third—A position at which materials and supplies required for consumption at the armory may be obtained at low prices, and with facility and certainty.

An estimate of the principal materials, required for annual consumption at an armory manufacturing twelve thousand muskets per annum, is enclosed herewith. In forming an estimate of the comparative advantages of the several sites which may be examined, a reference to this estimate of materials will be important; for, with respect to the article of coal alone, a difference of circumstances, which shall occasion a difference of price equal to one cent per bushel, will occasion a difference of one thousand dollars per annum in the expenditures of the armory.

Fourth—A position from whence the arms manufactured at the armory may be conveniently distributed to the various points in the Western country, which the public service may require. This consideration, although important, is considered subordinate to those which have been already enumerated; for the main purpose of an armory, is the fabrication of small arms, and it is not considered indispensable, that a depot, for the collection and distribution of other military supplies, should be connected therewith. Those circumstances, therefore, which may affect the quality of the arms, or the cost of manufacturing them, it is conceived, should form the primary considerations in the location of an armory. The materials required annually for the supply of an armory, according to the enclosed estimate, are about 966 tons weight; the arms manufactured annually will weigh about 80 tons. Therefore, the expense of transporting materials, compared with that of transporting the arms, an equal distance, will be as twelve to one.

The act requires an estimate of the amount necessary for purchasing each of the sites which may be examined. On this subject I would remark, that the limiting of the purchase of land for public works to a small quantity, and just sufficient for purposes immediately contemplated, has not unfrequently proved greatly disadvantageous to the public interest. I would therefore recommend, that the estimates be calculated for the purchase of at least a section of land, or a quantity equal to one square mile. The act also requires an estimate of the amount necessary for erecting all necessary buildings for an armory. An estimate of the number, dimensions, and description, of the buildings necessary for the manufacture of twelve thousand muskets per annum, will be furnished.

The foregoing exhibits only what are deemed by this department the most important of the considerations connected with the selection of a site for a National Armory.

It is considered unnecessary to give any further details, as the gentlemen appointed to make the examinations are, from their talents and experience, fully qualified for the able performance of the duties which have been confided to them.

I have the honor to be, Sir, very respectfully, your obed't servant,

GEORGE BOMFORD,
Lieut. Col. on Ordnance duty.

Hon. JOHN C. CALHOUN.

ESTIMATE of the quantity of materials required for annual consumption at an Armory calculated for the manufacture of twelve thousand muskets per annum.

	Tons.
Refined iron, about	120
Steel, of various kinds	12
Brass and zinc	2
Emery	1
Grindstones	80
Sand	20
12,500 rough walnut stocks	44½
12,000 files, assorted	3
100,000 bushels of charcoal, or one-sixth of the quantity of pit coal	500
150 cords of wood	150
500 gallons of sperm. oil	2
100 do. linseed oil, and 4 barrels of tar	1
Band and buff leather	¼
Woollen rags	½
2,000 bushels of old shoes	8
50 coal baskets	½
Fire clay	20
30 reams of sand paper	¼
20 do. wrapping paper, for wadding	¼
Writing paper and stationery	¼
Tallow and candles	¼
Total	966

PHILADELPHIA, 13*th January*, 1825.

The Commissioners appointed by the President of the United States, under the act of Congress passed 3d March, 1823, entitled "An Act to establish a National Armory on the Western Waters," respectfully present their Report.

The task of arranging the various data, and estimating the expense, with the "advantages and disadvantages" of the several sites examined, has been more arduous, and has occupied more time, than was anticipated, even by ourselves.

Very respectfully, we are, Sir, your obedient servants,

W. McREE,
ROSWELL LEE,
G. W. TALCOTT.

To the Secretary of War.

REPORT

The undersigned Commissioners, appointed by the President of the United States, under the act of Congress, passed the 3d of March, 1823, entitled "An act to establish a National Armory on the Western Waters," assembled at Pittsburg, Penn. the 1st of June, 1823, and proceeded to view, and cause surveys to be made, of those sites which were generally considered to possess the necessary requisites.

The large proportion of the whole quantity of materials annually required at an armory, which will be necessary in all cases to transport across the mountains, and partly from the seaboard, furnished a sufficient reason, independent of any other, for restricting our examinations to sites within reach of convenient navigation; they were, accordingly, confined to those water courses falling into the Ohio, or on their tributaries, below the head of ascending navigation of the principal streams, with one exception, which will be mentioned in its place.

The examinations were not completed till near the close of December, and the Board assembled at Pittsburg at the end of that month. The returns of the surveys, levellings, &c. were not all received until the month of March following, when it was found impracticable to complete the necessary estimates for the several sites, before the adjournment of Congress; and they separated in June, with the intention of resuming their labor in sufficient season to lay their report before the present session of Congress.

The deep interest felt by the people of the Western States, and the importance of the subject to the nation at large, has made it an imperative duty to exhibit all the facts in their possession, which are considered necessary or useful, in deciding the location of the armory.

The sites on Shoal and Cypress Creeks, in Alabama; Harpeth river, in Tennessee; at the Falls of the Ohio; north bend of the Ohio, below Cincinnati; the Falls of the Muskingum, at Zanesville; Falls of Big Beaver; and at the Ohiopile Falls of the Youghiogheny river, in Pennsylvania; were found to unite considerations in their favor, that, under the considerations attending this inquiry, called for a more particular statement of their respective advantages and disadvantages; and have made it necessary to spread such a mass of details, without which, it would be difficult, if not impossible, to form a just estimate of their true value.

Those sites which were found, on examination, so deficient in essential particulars, as to render an estimate of the cost of improving them unnecessary, are noticed in the appendix to this report; to which paper reference is also made, for such statements and information as would be most conveniently embraced in that mode.

The average number of muskets now manufactured at the national armories, is about 12,000 stands, each, per annum. That number has, therefore, been taken as the basis of all our arrangements and estimates of the expense at the several sites hereafter mentioned.

To aid in forming a more correct idea of the advantages and defects of the several sites that will be described, it may be necessary to state the following particulars, explanatory of the requirements that are essential for an armory, as regards the extent of the water power, the necessary space for the buildings, and the general accommodation of the establishment. The measure of the water power used at the national armory at Springfield, Mass. has been taken as a standard. It is equal to that which, in the usual estimation of millwrights, is required for operating about twelve pairs of five feet burr mill stones; but, after making the necessary deductions, is found to be less than 1032 cubic feet of water per second, falling from the height of one foot, and acting by its gravity, or near double that quantity, when acting by percussion.

The number of buildings that will be required, is sixty-one; of which thirty-two are dwellings for workmen, and seven for the officers of the establishment. The aggregate length of the workshops, storehouse, and offices, is 1016 feet by 40 feet broad, exclusive of the space between them.

The number of workmen of different descriptions, required to manufacture 12000 stands of arms, annually, is estimated at two hundred and fifty.

The quantity and kind of materials, that will be annually required, in the fabrication of that number, is shewn in statement A of the Appendix.

It is considered unnecessary to offer any general view of the character and habits of the water courses of the Western country. The degree, as well as manner, in which they particularly affect the water power at the several sites, will be mentioned in the following description:

Shoal and Cypress Creeks, in Alabama, are rapid and permanent streams, and afford a number of advantageous sites for the application of their water power to machinery. Shoal Creek empties into the Tennessee River, opposite the Great Muscle Shoals, nine miles above the town of Florence. It is not navigable, nor is the communication by water from its mouth to the foot of the Muscle Shoals, considered practicable to any useful extent. The military road leading to Florence, crosses the creek about nine miles from the town, and about eight miles above its junction with the Tennessee. The United States have reserved a tract of land, seven miles square, at the forks of the creek, twenty-three miles from Florence, containing iron ore, of an excellent quality, and in large quantities, lying convenient to fuel, and an ample water power, for reducing it and forging the iron. The greatest natural fall that can be employed at any one point, between the southern boundary of the reservation and the forks of the creek, does not exceed seven feet. The freshets rise to a considerable

height, and the bottom lands resemble those of other water courses that are subject to overflow: but, below the military road, the bed of the stream becomes wider, its descent is also increased, and the current is confined for the most part within its banks, during the highest rises. A material change is accordingly observed in the nature of the bordering low grounds. The character of the surface is equally altered; and the bottoms, properly called, cease altogether. At every bend of the creek, the shore on the concave side is high and abrupt, and sometimes precipitous. The opposite side generally presents an inclined plane, rising gradually from the margin of the stream, and extending back to a considerable distance. Several of these positions were examined, and levels taken at one of them, called the Iron Shoals, four miles below the military road. The whole fall is eight feet five inches, in twelve hundred yards. The creek is five hundred feet broad at the head of the rapids, and its bed and both shores are of rock.

The extreme rise of its freshets at Brush Run, where the workshops would be placed, is stated to be ten feet: a dam ten feet high would therefore give a head and fall of near eight feet at the wheels, free from interruption of high water. The cost of the canal, forebays, races, &c. would be very moderate. The water might be taken from above the dam and conveyed to the works, on the same level with, or at any required depth below, the surface of the ground. The building of a weir and permanent water-tight stone dam, would comprise the chief part of the expense that would be required to improve the site.

A greater fall might, perhaps, be obtained nigher to the Tennessee river; but the immediate neighborhood of the Muscle Shoals is said to be extremely unhealthy, and it is by no means certain that the Iron Shoals, or any point below the Military road, would be altogether beyond their influence.

Cypress Creek empties into the Tennessee, below the great Muscle Shoals, and two miles below Florence. It is navigable one mile and a half from its mouth, with boats drawing two feet and a half water, for five or six months in the year. Its shores resemble those of Shoal Creek, below the Military road, in almost every respect that has relation to the use of its water: if there is any difference, it is rather in favor of the fomer. Its slopes are, in some cases, even more gentle and uniform. The most advantageous site for an armory is at Clopper's Mills, three or four miles from Florence, and about three miles from the Tennessee by land. A fall of fourteen feet and a half can be obtained in the distance of 1470 yards. The highest rise of the creek at the point where the works should be placed, is stated at ten feet. A dam, eight feet high, would therefore give a head and fall of near twelve feet, that may be used on breast wheels free from interruption. The bed, and both shores of the creek, at the head of the rapids, are of rock, and afford a secure position for the dam. The surface of the ground, through which the canal would pass, is perfectly at command, and the depth

of the excavations may, therefore, be regulated at pleasure. It will be proper, however, to take the canal through deep cuttings, as far as the point at which a weir would be placed in order to secure it against the effect of any accident that might happen to the head-gate, near the dam, during a freshet.

The quantity of water which either of these creeks furnish at their lowest stage, could not be ascertained. At the time they were examined, the volume of Shoal Creek appeared to be a third greater than that of Cypress: either of them, however, contained several times the quantity that would be necessary, with a head and fall of ten feet; and those most acquainted with both, and best qualified to form correct opinions on the subject, were confident that there is little or no difference in the quantities delivered by the two streams, when each is at its lowest stage. So far, therefore, as these circumstances may authorize any conclusion, it appears that the power which may be employed at Clopper's Mills, is greater than any that can be obtained on Shoal Creek. In other respects, the position at Clopper's Mills is preferable. It is considered to be healthy, and has the advantage of being within convenient distance of the Tennessee river.

The following estimate will show the probable quantity of labor and materials that will be required at this site:

Excavations of Earth.

For the forebays and races:	
5734 cubic yards, from 10 to 12 feet deep, at 14 cents per yard, - - - - - -	$802 77
4103 cubic yards, from 2½ to 5 feet deep, at 8 cents per yard, - - - - - -	328 28

For Canal.

10,500 cubic yards, 18 feet deep, at 22 cents per yard,	2,310 00
25,140 cubic yards, 9 feet deep, at 12 cents, - -	3,016 80
6,690 cubic yards, 11 feet deep, at 15 cents, - -	1,003 50
For the weir, 1,111 cubic yards, 3 feet deep, at 6 cents,	66 66

Masonry.

Walls for forebays and races:	
2,968.24 cubic perches, at $2 12½ per perch, - -	6,307 51
326.52 cubic perches, at $4 25 per perch, - -	1,387 71
Canal—wall at the work-shops—wall near the dam, and walls of the weir:	
2,919.3 cubic perches, at $2 12½ per perch, - -	6,203 57
505 cubic perches, at $4 25 per perch, - -	2,146 25

Stone Dam:

1,560 cubic perches of large size, and dressed to dimensions, excavations for foundations, &c. filling, covering, and other expenses included, - -	8,775	00
Bridges over the canal and forebays, two at $100 each, and five at $25, - - - -	325	00
Head gate of canal, near the dam, 17 feet high, including masonry and fixtures, - - - -	359	00
61 buildings, including quarters for officers and workmen, workshops with fixtures, offices, &c. -	148,501	78
Machinery and tools, patterns, &c. - - -	14,522	00
Miscellaneous articles, - - - -	1,549	00
	$197,604	78
Add for contingencies 10 per cent. - - -	19,760	47
Purchase of —— acres of land, including Clopper's mills, water-rights, - - - -	15,000	00
Aggregate, - -	$232,365	25

This estimate is founded on two assumptions: first, that eleven feet head and fall may be employed on breast wheels without being interrupted by freshets, and second, that the quantity of water at the lowest stage of the creek is not less than 138 cubic feet per second, both of which are indeed probable, but neither of them certain. In case that part of the fall which may be employed on breast wheels, should prove to be less than what is here supposed, and the volume of water no greater, it would be necessary to employ a portion of the remaining part (ten feet) on reaction wheels, and consequently, the surface of the water in the canal, as far as the first work-shop, must be permitted to rise and fall with that of the stream above the dam, at least to the height of four or five feet; hence, the excavations of the forebays, races, and of the canal, might require to be augmented to twice, and the masonry (excepting for the weir,) to four times the amount stated in the estimate. In like manner, a deficiency in the quantity of water that is assumed would compel a resort to the same remedy, and be attended with similar consequences, admitting the power in each case to be sufficient, when so employed.

There is also considerable uncertainty in relation to the prices—in some instances, no specific information could be obtained.

The United States own a quantity of vacant land in the immediate neighborhood of Clopper's mills, and seven or eight quarter sections adjoining the tract which includes the site; stone coal has not been found nearer than the Cumberland Mountains, and the expense of its transportation would probably exclude the use of it at the armory.

The Tennessee river is navigable for steam-boats, from Florence to Ohio, six months in the year, and from Waterloo, thirty miles below, at all seasons. Keel-boats run the whole year, and sometimes ascend the Muscle Shoals.

Colbert's Shoal, on which there are twenty-two inches depth of water at the lowest stage of the river, is the only impediment to the navigation between Florence and Waterloo.

From the mouth of Bear Creek, near Waterloo, to Cotton Gin Port, on Tombeckbee, is sixty miles on a direct line; thence, to Columbus, the river may be navigated by keel-boats several months in the year.

From Florence to Columbus, by the military road, is 121 miles; and 135 miles to Tuscaloosa, at the Falls of Black Warrior, by the road now in use. The navigation of the Black Warrior, below Tuscaloosa, and the Tombecbee, below Columbus, is stated to be good at all seasons for keel-boats, and a part of the year for steam-boats.

Narrows of Harpeth River, Tennessee.

Twenty-two miles above its mouth, the Harpeth river makes a circuit of 4½ or 5 miles, embracing, and nearly insulating, at high water, about one thousand acres of land. The neck which joins this tract to the country on the right of the river, is called the "Narrows;" it is a limestone ridge, several hundred yards long, varying from 60 to 150 yards broad at its base; and from 60 to 250 feet high. The whole descent of the river, in its course from the upper until it reaches the lower side of the Narrows, is 17 feet, a tract of bottom land, of several hundred acres, terminates at this point; and a lagoon or bayou, which runs along the foot of the ridge, and separates it from the bottom, at a medium stage of water, empties into the river at the same point. One hundred and forty yards above the mouth of the bayou, a tunnel, 96 yards in length, 15 feet wide, and 6 feet high, has been excavated through the ridge. The bottom is here between one and two hundred yards wide, including the bed of the bayou, and is the site which has been proposed for a national armory. On the plan H No. 2, is a section of the tunnel, and profile of the ground, on a line passing over the lower part of the site, from the outlet of the tunnel to the river. The average elevation of the ground along this line, between the bayou and the river bank, is nine feet, its greatest elevation above low water mark is twelve feet; and no where within the limits of the site is the surface three feet higher. The highest rise of the Harpeth, as well as the height of its ordinary freshets, has not been satisfactorily ascertained. The surveyor who was employed to take the levels at the Narrows, is one of the oldest settlers in that neighborhood, and believes that he has seen it rise to the height of 33 feet above low water; but at a point 24 miles *above* the Narrows. A mile and three quarters *below* the Narrows, he found a water mark, left by the freshet of 1808, to be more than 29 feet high, and a rise that took place in the winter of 1822, he states to have been 18 feet, a quarter of a mile below the Narrows. These statements, however, have been controverted. We have received, through a most respectable channel, cer-

tificates of individuals residing at the Narrows, or in its vicinity, in which it is asserted that the highest rise of the Harpeth, in the last 13 years, did not exceed 16 feet. Several gentlemen from Nashville were also employed to ascertain the greatest known elevation of the river, who report 21 feet to be the height of the water mark which they measured, and which is said to have been made by the greatest freshest that has occurred within the recollection of the oldest inhabitants. It is also mentioned that considerable obstructions to the current existed at that time (1808) which have since disappeared and it is hence inferred, that an equal rise of the river cannot be anticipated for the future.

We cannot question, and do not doubt the accuracy with which these measurements were made, but we are constrained to infer the probability of some error in the data on which they were founded Our personal observations corroborate the statements made to us by the surveyor. We traversed the river bottom from the outlet of the tunnel to the river bank, and thence in various directions; the character and general appearance of the ground gave ample evidence, in our opinion, of frequent, if not annual, inundations. The alluvion deposite, on the bark of the trees, was sufficiently recent to be removed in some instances by the hand: and similar appearances, supposed to be water marks, were observed above our heads, and higher than we could reach, although on horseback. All the documents relating to this site, that have been transmitted to us, are marked H, numbered from 1 to 15, and accompany the report.

From the mouth of the lagoon before described, the river pursues nearly a straight course along the foot of the ridge for more than 600 yards, when it changes its direction to the left, leaving between it and the hills to the right, a body of high level ground, sufficiently elevated and extensive for all the purposes of an armory; its surface is 45 feet above low water, and works might be conveniently placed on the banks of a bayou, that forms an island in front of the site. To convey the water to this point, it would be necessary to build a river wall, extending from the outlet of the tunnel to a ravine that empties into the river, at the upper end of the site; its dimensions will depend on the greatest heights to which the Harpeth may be supposed to rise. If it is assumed to be 25 feet below the narrows, and that 4 feet head is employed on the wheels when the river is at that elevation, the least height of the wall should not be less than 31 feet above the level of low water, its length will be 2136 feet, including the returns at the two ends connecting it with the cliff above the tunnel, and with the ravine that communicates with the head of the canal.

The length of the canal will be only 640 feet, or 20 feet longer than the range of work shops; but the mass of the excavations will be 33 feet deep, besides a large portion of the river bank that must be removed to the average depth of 10 feet.

The supply of water in the Harpeth, during its lowest stage, is not known; the quantity, however, is considered to be sufficient, in the

driest seasons; and, by using reaction wheels, the power will be rendered permanent without a dam. The probable cost of occupying the site below the narrows, is estimated at $357,940, viz:

Excavation of 105,283 cubic yards of earth, for canal; forebays, races, &c. at different depths, from twelve to thirty-three feet - - - -	$28,630 90

Masonry.

For forebays, races, river wall of the shops, 13,068 perches, at $2 16 per perch - - -	28,226 88
For arches and flagging 188 perches, at $4 32 -	812 16
For canal wall, and river wall, from the tunnel, 33,373.05 perches, at $2 16 - - - -	72,085 78
Two bridges over canal, at $100 each - -	200 00
Four bridges over forebays, at $25 each - -	100 00
Head gate to the tunnel, thirty feet high, including masonry, fixtures, &c. - - - -	698 18
Sixty-one buildings, including officers' quarters, thirty-two dwellings for workmen, offices, and workshops, with fixtures for machinery - . -	164,030 02
Tools and machinery - - - -	14,522 00
Miscellaneous articles - - - -	1,549 00
	$310,854 92
Add for contingencies, ten per cent. - -	31,085 49
	$341,940 41
Purchase of 450 acres of land, and water privileges	16,000 00
Aggregate	$357,940 41

It is to be observed, of this site, that the fall employed is the whole descent of the river in the distance of five miles, which differs but little from the rate of its descent, either above the head, or below the outlet of the tunnel; it is probable, therefore, that the river rises equally high at both places; and, when at its greatest elevation, that the column of water, pressing against the outer side of the head-gate, will be fourteen feet higher than the column which sustains it within.

Any accident that might happen to destroy, or remove the gate, or in any other wise give a free passage to the water, at that time, would be followed by the immediate ruin of the river wall, and would put a stop to the operations of the armory.

The danger might be removed, however, by the use of additional head-gates, to divide the pressure of the column of water; and would be preferable to a wier, which, at this place, would not cost less than twelve or fifteen thousand dollars.

The mode of conveying the water to the work shops, by means of a river wall, is an inconvenience attending the position of the present

tunnel, which remains to be noticed. The wall must be placed in the bed of the river, and the current would strike against it, near the mouth of the lagoon, at an angle of forty degrees. We should prefer to abandon this tunnel, and to open another, through the hills, entering about 500 yards above the head of the old tunnel, and taking it direct to the ravine near the workshops. Its length would not exceed four or five hundred yards; and, allowing the excavation to be made sufficiently high to leave the roof as it ought to be, above the surface of the water, when at a medium, or even a higher stage, it would, probably, cost less than the river wall, but would require equal precautions against accidents to the head gate. Two hundred thousand acres of vacant lands lie adjacent to the site, and all within five miles of it has been appropriated by an act of the State Legislature to the use of the General Government, in case the armory should be located at the Narrows.

The resources of the neighboring country, in reference to the wants of an armory, consist chiefly of fuel, (fire wood) building timber, and iron. Several furnaces and forges are in operation within a few miles of the site. A ton of iron, from the works of Colonel Napier, was sent to the armory at Springfield, during the last season, and proved, on trial, to be equal in quality to any that is found in commerce, and only inferior in the refining to the best warranted Salisbury iron, made especially for that armory, and for which twenty dollars per ton extra is paid.

The distance from the Narrows to the Cumberland River, is less than ten miles on a straight line, and about twenty miles to Nashville; the road leading from the latter place to Charlotte, passes within a mile or two of the site. Harpeth River is said to be navigable from one to four months in the year, for boats drawing three feet water. Steam boats ply on the Cumberland river during five months in the year; keel boats about ten months, and sometimes the whole year. It is never obstructed by the ice, unless by that of the Ohio near its mouth; and the general character of its navigation, below Nashville, is said to equal that of the Ohio between Pittsburg and Louisville.

The Falls of the Ohio are occasioned by an irregular bed of horizontal limestone, about two miles broad, that forms a natural dam, twenty-five or thirty feet high above its base, and extending obliquely across the river, from between Shippingport below, and Louisville above, the falls, on the Kentucky side, to the upper end of Clarksville below, and Jeffersonville above them, on the Indiana side.

The course of the Ohio, until it passes Jeffersonville, is nearly parallel to the upper limit of this obstruction; opposite to Louisville, the river changes its direction to the right, and, after passing over the bed of limestone, to the foot of the falls, it again changes its direction between Clarksville and Shippingport, resuming, very nearly, its original course, and leaving Shippingport on a point of low bottom to its left.

Louisville stands on an elevated plain, nearly opposite to the head of the falls. A short distance below the town, the high ground re-

cedes from the river, leaving an intermediate body of low bottom land, that extends and gradually enlarges, in the direction of Shippingport, where it is nine hundred or a thousand yards wide. The upper side of the bed of limestone quits the Kentucky shore at the lower end of Louisville, making an acute angle with the course of the river bank above; and leaving a secure and tolerably commodious harbor in front of the town, and extending upwards as far as the mouth of Bear Grass creek. The termination of this harbor or basin, is the point from whence the water must be taken to any site on the Kentucky side. The rock, near the head of the falls, is left bare at low water, for a considerable distance from the shore, on both sides of the river. It is exposed for ten or twelve hundred yards below the basin, and five or six hundred yards in front of it, and before Louisville, forming a level plain about a foot above low water, and connecting Corn Island, near the head of the falls, with the Kentucky shore. On the opposite side, below Jeffersonville, it extends to a greater distance along the margin of the river, but has a less width.

The right bank of the river, from Jeffersonville, nearly as far as Clarksville, is high, and not subject to overflow, with the exception of a narrow strip of low bottom, eighty or one hundred yards broad, in places that will be noticed hereafter. Near the upper end of Shippingport, and immediately at the foot of the falls, is Rock Island. It is the first of a succession of low islands, that extend more than a mile up the river, and terminate in a reef of rocks, that reaches to the head of the rapids. This chain of islands and reef divides the river into two unequal channels, with very unequal descents, as far as Rock Island. The Kentucky channel is again divided, but in a manner that will not affect the use of the water power, and therefore does not require to be described.

Fourteen hundred yards below the head of the falls, the descent in the channel next to the Indiana shore, is seventeen feet: and immediately opposite, on the Kentucky side of the river, the descent is only seven feet. This difference of level continues to the forebay of Tarascon's mills, at the upper end of Shippingport, where the whole descent is only eight feet four inches, and is the largest portion of the falls that can be employed at an Armory, without going near to Portland, about half a mile below Shippingport, where the ground affords sufficient space for the buildings. Thus, there are three sites at these falls: one above Tarascon's mills; another between Shippingport and Portland; and the third below Jeffersonville, Indiana; all very differently circumstanced, and will require to be considered separately.

But, as the height and continuance of the periodical rises of the river, and particularly the relation which subsists between the successive rises immediately above and below the falls, in connection with the height of the whole fall at low water, will influence materially the expense, if not the security of the works, as well as the term of interruption to the power at each of these sites, it will be proper in the first instance, to present such facts and circumstances concerning them, as are in our possession, and which governed in the estimates.

The highest rise within the recollection of the inhabitants, is stated from 35 to 37 feet, at Louisville, and from 56½ to 61 at Shippingport. A plan and profile of the bed of the river next the Kentucky shore, between Louisville and Shippingport, from a survey by Mr. Torren in 1819, makes the height of the freshet in 1817, to be 35 feet above low water at the mouth of Bear Grass creek, and 60 feet 7 inches at Shippingport. Mr. Flint, the Engineer employed by the Ohio Canal Company, states the rise at Jeffersonville in 1815, to have been 37 feet above the lowest stage in 1819, which accords exactly with the measurement from water marks at Bear Grass and Jeffersonville, made by the surveyor, under our direction.

The falls have been frequently surveyed, and levels taken to determine their height; but generally without ascertaining the stage of water at the time, otherwise, it would seem, than by estimate or conjecture, and from which the whole descent of the river, at extreme low water, is then calculated; hence, it is variously represented, from 22½ to 27 feet. So, also, the height of the greatest rise at Shippingport, appears to be generally inferred from its height at Louisville, where the low water marks may be ascertained and measured from, with more certainty and ease than below. The greatest portion of the whole fall, actually measured by any individual, appears to have been done by Mr. Flint in 1819, who found the difference of level, between the surface of the river at Jeffersonville and the northwest point of Rock Island, near the upper end of Shippingport, to be 24 feet 5½ inches, when the river was at its lowest stage in that year, and only 8 inches depth of water on the bar at the head of the falls.

Mr. Torren, on his plan and profile, above referred to, lays down the whole fall, at extreme low water, at 26 feet, but expressly as calculated at 4½ inches depth of water on the bar, which is the least depth ever known upon it. The calculation, then, must have been made subsequent to the survey in 1819; at which period, the least depth of water on the bar, was ascertained to be greater than what he states it.

But, as his levellings were carried to a point below Rock Island, and as the Ohio river was subseqently lower than in 1819, his estimate of the whole fall (if it be taken for a period of extreme low water) will correspond sufficiently with the levellings of Mr. Flint in 1819, and may be considered as the nearest approximation to the truth, which a comparison of all the data in relation to the subject will admit.

The ratio between the rise of each successive foot at Louisville, and the corresponding rise at Shippingport, counting from any given stage of the river, up to its greatest elevation, is not known. It has been determined, however, with sufficient accuracy, to an extent that will be useful in the present inquiry.

In 1809, Mr. Nicholas Berthoud, of Shippingport, with the assistance of another gentleman at Louisville, ascertained, from a series of daily observations, the relative rise of the river at both places, for several successive feet above low water. Each foot of rise above the

falls, during the first three feet, was accompanied by a uniform rise of 4 feet below, making the whole rise below, 12 feet; and 3 feet above. The ratio then changed, and continued to decrease. At the 7th foot rise above, the whole rise below was 24 feet; and at the 9th foot above, it was about 28½ feet below. Some doubts, however, were expressed to us as to the accuracy of these memoranda after the 7th foot. The actual difference of level between the surface of the river at Louisville and Shippingport, at the commencement of these observations, was not known. Nor is the circumstance very essential, as it can be determined with sufficient exactness for the present purpose from other data. The levellings and measurements of Mr. Flint, shew, that the ratio of 4 for 1, only begins at a certain elevation of the river; and that, when the fall was more than 24 feet in 1819, and the depth of water on the bar was less than one foot, above extreme low water, the ratio was less than two for one.

The whole descent, from Louisville to Shippingport, must, therefore, have been less than 24 feet at the commencement of Mr. Berthoud's observations in 1809. If 24 feet is taken as the fall at that time, it will appear that the whole descent of the river was only 7 feet, when the rise observed at Louisville was 7 feet; and, by continuing to diminish the ratio for the three succeeding feet, above that rise, in the same degree that it is found to diminish, in the 3 feet preceding it, the fall will be 3½ feet, when the river at Louisville is 10 feet above its level, at the time the observations were begun. From whence it will follow, that the power at an armory below Shippingport, will prove inconvenient, if not inefficient, in its operation, when the river shall have attained but little more than one-fourth its greatest elevation at Louisville, and that it will cease altogether, before the river shall have attained to one third its greatest elevation at that place. These results are much more favorable to the duration of the power, than those derived from another respectable authority. A scale constructed by the Engineer, Mr. Brooks, to show the action of the water on the falls, makes the whole difference of the level between Louisville and Shippingport to be only 3 feet, when the rise on the bar, at the head of the falls, is 7 feet, above extreme low water, at which period the whole fall is laid down at 24 feet. The power, according to this scale, would, therefore, be totally interrupted when the river shall have reached one fifth its greatest height at Louisville. We have adopted the observations of Mr. Berthoud, however, as more authentic; and it has governed in the calculations for the canals, walls, &c. for the different sites. Both scales are placed in the appendix.

Site below Shippingport.

This site embraces the outlets between Shippingport and Portland, and will admit of using whatever portion of the whole fall may be found most advantageous.

The ground is sufficiently extensive, and although that part next the river is first on low bottom, it is but seldom overflowed, and is covered but a few feet by the highest freshets. The embankments necessary to secure it from this inconvenience, will cost but little, and may be made secure; and in case any accident should happen to them, during the freshet, the consequences could not be serious. These remarks, however, only apply to that part of the ground adjoining Portland: near to Spippingport, the river bottom is much lower; but, as the object of the estimate is to determine the least expense which would attend the occupation of any site below this place, the works are supposed to be located as near to it, as a ravine, at its lower end, will permit; and the length of the canal is reduced several hundred yards, in consequence. The water would be conveyed to this site, from the lower end of the basin, before Louisville, by a canal, 3355 yards long. In the first 773 yards, it will pass through the Rock Plain, that connects Corn Island with the shore at low water: the remaining part of the distance will be through the low bottoms, to the lower end of Shippingport, and thence, parellel to the river bank, in the direction of Portland, as far as the position of the last work-shop.

ESTIMATE OF THE EXPENSE FOR AN ARMORY BELOW SHIPPINGPORT.

Excavations of—Earth.

For forebays, races, &c.	
17,785 cubic yards, from 16 to 20 feet deep, -	$4,077 26
For canal:	
239,714 cubic yards, 16.7 deep, at 18 cents per yard,	43,148 52
41,651 cubic yards, 28 feet deep, at 34 cents per yard,	14,161 34

Of Rock.

For forebays, races, &c.—levelling for foundations of walls:	
439 cubic yards, at 50 cents per yard, - -	217 77
For canal:	
4,489.62 cubic yards, 4¾ feet deep, at 66 cents per yard,	2,963 15
27,982.96 cubic yards, 7¾ feet deep, under 16.72 depth of earth, at $1 25 - - - -	34,978 70

Masonry.

Walls for forebays and races:	
2,289.77 perches, at $3 per perch, - -	6,869 32
Arches for do.	
747.49 perches, at $4 75 per perch, - -	3,550 57

River wall and piers:		
15,875.02 perches, at $2 75 per perch, - -	43,655	55
Walls for canal, at the shop at Ravim:		
7,372.85 perches, at $2 75 per perch, - -	20,275	33
Bridges:		
Two, at $100 each, - - - -	200	
Head-gate to canal, 44 feet high, above bottom of canal, including the masonry, &c. - -	2,181	96
Buildings, including work-shops and fixtures, for machinery, &c. - - - -	173,142	32
Tools, machinery, and miscellaneous articles, -	16,071	
	$365,492	79
Deduct, for stone excavated from canal, and used in building walls, - - - -	6,571	28
	$358,921	51
Contingent expenses, estimated, at ten per cent.	38,792	15
	$394,813	66
200 acres of land, embracing lots of Shippingport and Portland: value not known. - -		
Aggregate - -	$	

It is proper to mention a circumstance that may add materially to the expense of occupying this site. We have no information respecting the position of the rock below the surface of the ground, other than what is furnished by the experiments of Mr. L. Baldwin, who surveyed a route for a navigable canal round the falls in 1815, under the direction of the Ohio Canal Company, and bored the ground in nine different places on the line of the location, to ascertain the distance of the rock below its surface. The route of the proposed canal, for an armory below Shippingport, follows a straight line from the point where it first enters the low bottom at Louisville, until it reaches the lower end of Shippingport, and would pass very nearly over the same ground with that located by Mr. Baldwin.

We have, therefore, adopted his profile and sections of the ground, reducing the points at which his borings were made, to corresponding points on the straight line. It appears, from this profile, that the surface of the rock gradually declines in the direction of Shippingport, and, at the distance of 700 yards from the river, sinks below the level of low water above the falls; the last boring is at a point 290 yards from the river, and the surface of the rock is there 7 feet below that level. The straight line of the canal continues 220 yards beyond this point, to within 70 yards of the river, below Shippingport; and, thence, 300 yards parallel to the river bank, in the direction of Portland. The surface of the rock in the latter distance, is assumed in

the estimate to be nine feet below the level of low water in the canal, and the dimensions of the walls are regulated accordingly.

There is no other reason for supposing it may be found at that depth, along this part of the route, than what may be inferred from the borings of Mr. Baldwin.

It certainly does not extend to the river at the site; nor is it any where exposed to view at the river bank below Shippingport, and it may terminate several hundred feet above the workshops; in which case the additional quantity of masonry that would be required beyond the amount stated in the estimate, might exceed eighteen thousand perches.

Site above Shippingport, near Tarascon's Mills.

This site is near the upper side of Shippingport, and five hundred and seventeen yards above Tarascon's Mills; the whole descent of the river is eight feet.

It has the advantage over that below Shippingport, of a secure rock foundation, elevated several feet above low water, on which to build the river wall and other masonry.

The water would be taken, as in the former case, from the basin before Louisville. The canal would pass 1058 yards through the rock plain, between Corn-Island and the shore, to where it enters the bottom land; and, from thence, it will pursue a straight course, 1400 yards, to the workshops, through the low river bottom. The earth, in these distances, averages 19.36 feet above the surface of the rock; the rock averaging 3.97 feet above the level of low water at Louisville.

In whatever manner the fall at this site may be divided between the descent of the canal and the head employed on the wheels, the excavations must necessarily be great.

In the estimate of the expense, the wheels are supposed to be placed only six inches above low water, which is necessary to leave the head employed on them, the power that is assigned to it at that stage of the river. The rest of the fall is divided between the descent of the canal and the head employed on the wheels, and will require more than 500 cubic feet of water per second. This distribution of the fall is made exclusively with a view to economise the expense of the excavations, and will evidently be inconvenient, even with reaction wheels, and impracticable with any other kind. They will remain submerged not less than nine or ten months in the year, and frequently the whole year.

Estimate of the expense for an armory at the site above Shippingport.

Excavations.—OF EARTH.

For forebays, races, &c. at the workshops, 26,893.4 cubic yards, from 14 to 28 feet deep - -	$7,022 85
For the canal, 103,910.9 cubic yards, averaging 17.1 feet deep, at 21 cents per yard - -	21,821 29
42,581.75 cubic yards, averaging 29.5 feet deep, at 36 cents per yard - - - -	15,329 43

OF ROCK.

For forebays and races, 1,619.99 cubic yards, from 6.5 to 9 feet deep - - - - -	1,342 88
For the canal, 25,282.4 cubic yards, averaging 5 feet deep, at 66 cents per cubic yard - -	16,686 38
30,689.1 cubic yards, averaging 13.54 feet deep to bottom of canal under 17.15 feet of superincumbent earth at $1 37½ cents per cubic yard -	42,197 51
4,640 cubic yards 11.79 feet deep, under 29.5 feet of earth, at $1 60 per cubic yard - - -	7,424 48
Embankment at the upper and lower sides of the site, 12 feet average height, 42,854.9 cubic yards of earth required, at 15 cents per yard - -	6,428 24

Masonry.

Walls for forebays and races, (vaulted) 717.25 perches, at $3 per perch - - -	2,151 75
For the arches, 852.53 perches, at $4 75 - -	4,049 76
River and canal walls at the workshops, 17,527 perches, at $2 75 cents per perch - -	48,199 38
Head gate for the canal, 45 feet, including masonry, &c. - - - - - - -	2,841 96
Two bridges over the canal, $100 each - -	200 00
Buildings and fixtures for the machinery - -	172,617 32
Machinery, tools, and miscellaneous articles -	16,071 00
	$364,384 33
Deduct for stone excavated from the canal, and used in building the walls, 19,068.88 perches, at 75 cents per perch, - - - -	14,322 66
	$350,061 57
Contingent expenses, estimated at 10 per cent. -	35,006 15

300 feet of land fronting on Mill street, and between it and the Ohio river, at the upper end of Shippingport, J. A. Tarascon owner, offers at $50 per foot - - - - - -	15,000 00
100 acres of Lytle's land, offered at - -	105,000 00
Aggregate	$505,067 72

100 acres land additional required for the site, price not known, including about three acres divided into out-lots, number and extent of lots not known, rated at $20 per foot, front on the streets.

The excavations in this estimate can only be diminished by diminishing the head of water on the wheels, and augmenting the descent of the canal by the difference, in order to obtain a less area for its transverse section, by increasing the velocity of the current in a greater ratio than the quantity of water; but this would be a substitution of one inconvenience for another.

Besides, the head employed on the wheels is already reduced to four feet, at extreme low water, and the velocity of the current in the canal is between four and five feet per second through the rock, where the depth of the excavation is greatest; and if this velocity could even be increased at low water, it would cause it to be too great at the period when a rise in the river should raise the water in the canal above the surface of the rock, and bring it in contact with the earth sides above.

Levels were taken on four different lines, extending across this site from the river bank, to the high ground in the rear. The greatest elevation of the surface on either of these lines, is 6.66 feet below the level of the highest rise of water at Louisville. The greatest average elevation of the surface, on any of these lines, is 11.56 feet below the same level.

The highest part of the site is near the position occupied by the workshops and other buildings; and the distance from the river to the nearest part of the high ground back of it, is eight hundred and fifty yards.

The excavations from the canal will be sufficient to make the embankment on the side next to and between it and the river. From the point where the canal first enters the river bottom to the nearest high ground, (a distance of ten hundred and fifty feet) and from its termination at the workshops, to the nearest part of the high ground back of Shippingport, a distance of two thousand four hundred and ninety-one feet, the embankments will average 15 and 12½ feet in height, respectively. The utility of these embankments may justly be questioned, unless their dimensions are made sufficiently great to prevent all hazard of accident. To omit them altogether would be attended with great inconvenience, during the prevalence of a flood that should rise above the service of the site, although but little danger might ensue to the works. On the contrary, whatever convenience they might afford during the continuance of ordinary freshets, might be dearly paid for by any accident that should open a passage to the water, when

the river was at an elevation equal to that of 1815. During the high freshets, the water can be admitted into the canal only to within eight or nine feet of the extreme elevation of the river, without flooding the site. The difference in the pressure of the two columns of water, at the elevation of forty-two and thirty-four feet, respectively, on the outer and inner sides of the head gates, would then be such, as to warrant serious apprehensions for their security, and would either require the use of additional head gates to divide the pressure, or to subject the site to the inconvenience of partial inundation. A plan has been proposed for using the water at this site, different from that which we have adopted, and which it may be proper to notice. It is to build a wall in the bed of the river, extending from the upper workshops to the foot of the falls, a distance of seven hundred and twenty-seven yards, and at a sufficient distance from the works to permit the intervening space to be used as a tail race, and, by damming out the river opposite to the works, to enable breast or undershot wheels to operate, until they are stopped by the refluent water from below the falls. The object might no doubt be accomplished by the means suggested, and the duration of the power prolonged materially beyond the period at which it would be interrupted, if these wheels were left exposed to the rise of water in front of the works. The use of re-action wheels, however, answers an equal or better purpose, without the aid of the river wall. Besides, the proposed plan would compel the United States to purchase the whole of Mr. Tarascon's very valuable property along the margin of the river, including Rock Island, for which he asks two hundred thousand dollars; and this, in addition to the quantity of ground that is at present required for the site.

Site below Jeffersonville.

It has already been stated, that the descent of the river on the Indiana shore is seventeen feet at a point fourteen hundred yards below the head of the rapids. The ground at this place is high bottom, that never overflows, and affords an advantageous position for the erection of the necessary buildings for an armory. A narrow bench or strip of low bottom extends along the front of the high ground as far up as Jeffersonville, and is sufficiently wide below the head of the rapids, and at the site, to afford convenient space for the canal and workshops.

Between this bench and the river, at low water, the rock is left bare, to the distance of one or two hundred yards. According to the plan adopted in the estimate for this site, the canal will pass about 800 yards through this bed of rock, from a point 180 or 200 yards above the head of the rapids, to where it enters the low river bottom; and from thence to its end, the distance is 676 yards. The surface of the rock, in the first 800 yards, averages less than 18 inches above low water, at the head of the canal. In the remaining

676 yards, its average height is about 4 feet, under superincumbent earth, that varies from 17 to 24 feet deep.

The excavations of earth, from the canal, would be sufficient to raise the embankment, next the river, to a level with the adjacent high ground; and the work-shops might be placed nearly at the same height with the rest of the buildings.

Estimate of the expense for an Armory below Jeffersonville.

Excavations of Earth.

For forebays and races:	
9,839.82 cubic yards, of different depths, - - -	$1,549 24
For Canal:	
35,924.4 cubic yard, averging 17 feet deep, at 21 cents per yard, - - - - - -	7,544 12
27,592 cubic yards, averaging 24 feet deep, at 28 cents per yard, - - - - - -	7,725 76

Of Rock.

For forebays and races:	
4,670.38 cubic yards, of different depths, - -	3,946 73
For Canal:	
11,209.3 cubic yards, from 3 to 6.43 feet deep, 75 cents per yard, - - - - - -	8,406 97
10,225.34 cubic yards, 11.04 feet deep, under 24 feet depth of ground, at $1 50 per yard, - -	15,337 95

Masonry.

Walls for forebays and races, vaulted:	
439.757 perches, at $3 per perch, - - -	1,319 27
River wall, piers, and walls for canal, next the work-shops:	
13,480.519 perches, at $2 75 per perch, - -	37,071 41
Arches for forebays and races:	
852.58 perches, at $4 75 per perch, - - -	4,049 76
Two bridges over canal, $100 each, - -	200 00
Head gate, 44 feet high, including masonry, &c. -	2,181 96
Buildings, including fixtures for machinery, &c. -	168,570 25
Tools and machinery, including miscellaneous articles,	16,071 00
	$273,974 42
Deduct for stone, excavated from canal, and used in the walls:	
14,772.85 perches, at 75 cents per perch, - -	11,079 64

Contingent expenses at 10 per cent. - -	26,289 47
87¼ acres of land, offered at different prices, from 30 to $100 per acre, amount to - - -	5,785 00
Hughes & Co's. mill and water-rights, - -	12,000 00
312½ acres additional, price not known, estimated at $40 per acre, - - - - -	12,510
Aggregate, - - -	$319,479 25

A greater head of water is employed on the wheels at this site, and a greater descent allowed to the canal, without inconvenience to the works, than the whole amount of fall can furnish at the site above Shippingport. These advantages, together with the circumstance of its requiring a much shorter canal, give to it a great superiority as regards the relative expense of establishing an armory at the two sites, and as relates to its security; it is exposed to no hazard, that is not common to all situations on the margin of a large river, that is subject to equal high rises with the Ohio. The water may be admitted into the canal on a level with the highest freshets, without interfering with any of the buildings, or producing any serious inconvenience to the works. The power will be interrupted sooner than at the site between Shippingport and Portland, and probably not so soon as at that above Tarascon's Mills. The difference in this respect, however, cannot be estimated, nor can it be considerable. Supposing the power to continue effective, at the site near Portland, until the rise at Louisville exceeds nine feet, the power, at the site above Tarascon's Mills will probably continue to be efficient, until after the rise of the Ohio below Shippingport exceeds 24 feet. And at that stage, the descent of the river, at any two opposite points, taken on the Kentucky and Indiana sides, will no longer be in the same ratio, as at low water, but may approach nearer to that of the respective distances of these points, below the head of the falls; consequently, the power at Tarascon's Mills, with horizontal reaction wheels, may continue effective, for as long a period as at the site below Jeffersonville, although the former has only eight feet fall at low water, and the latter seventeen. There is an inconvenience, attending all of these sites, that has not yet been adverted to. The Ohio river, at its higher stages, carries, in its course over the falls, large quantities of sand, gravel, and stones, of considerable size. Judging of the extent of its agency in these operations, from the evidences which are exposed, at different places, at and below the falls, at low water, on both shores, there is great reason to apprehend that the upper part of the canals, where they pass through the rock plane, would be more or less obstructed, or, perhaps, entirely filled, by the deposite left by the river, during a single freshet. The evil, if it should exist to the extent here supposed, would require an expensive and inconvenient remedy. On the Kentucky side of the river, the course of both the proposed canals, where they are thus exposed, is nearly in the direction of the current, and

would retain whatever it might convey into them. They may therefore require to be secured by a mole or pier, extending from the basin before Louisville, to where they are taken into the low river bottom. These piers would require a head-gate, communicating with the shore, at their junction with the basin. The same expedient might likewise be found necessary for the canal at the site below Jeffersonville, although its position may possibly admit a more simple and less expensive remedy.

The length of time that the operations of an armory would annually be interrupted at these sites, by the high water of the Ohio, cannot be determined with much certainty. It is stated to us that Mr. Tarascon's mills were stopped, during six months, in 1822–3; that the ordinary period of the interruption, however, does not exceed three or four months. The forebay of the mills is eight feet below the head of the falls, and therefore does not furnish a criterion in this respect. But it has been shewn that the power will most probably cease to be efficient, at the site below Shippingport, before the rise at Louisville is ten feet, and that it will be totally interrupted, when the river rises above that height. According to the testimony of the pilots at Louisville and Jeffersonville, it appears that the depth of water on the bar, continues at or above the depth of six feet, from three to four months in the year, and continues four weeks at the depth of twenty feet, and six weeks at the depth of ten feet.

Plans S and L, No. 1, exhibit profiles of the two canals at Louisville.

Do.	2,	sections of the same.
Do.	3,	sections of embankments for the same.
Do.	4,	copy of L. Baldwin's profile.
Do. L	2,	profile and sections of canal, 2d project.
Do. J,	1,	profile of canal at Jeffersonville.
Do	2,	sections of the same.

No. 5 is a map of the Falls of Ohio.

North Bend of Ohio River, fifteen miles below Cincinnati.

The Great Miami River, eight or ten miles above its mouth, adjacent to the village of Cleves, approaches near the North Bend of the Ohio. The intervening ground is chiefly a lofty ridge, depressed at one point to one hundred and thirty-seven feet above the level of the Ohio, and falling off to the bottom lands on each side. It declines somewhat abruptly towards the Ohio, but leaves a broad plat of high bottom land, well situated for the location of the buildings necessary for an armory. The least distance of the Miami from the Ohio, is at a point below Cleves, and is about fifteen hundred yards. The difference of level in the waters of the two rivers, is here 28¾ feet. The bottom lands extend from this point upwards, including the village of Cleves, and along the left bank of the Miami, to the mouth of Jordan

Creek, a distance of three thousand yards. The average elevation of this bottom, taking the most advantageous route for a canal, is 21.5 feet above the level of the Miami, at the mouth of Jordan Creek, where the level of the water is 9.875 feet higher than at the point nearest the North Bend below Cleves. The bed of the Miami, when exposed to view, is composed of gravel and loose stones to a considerable depth, evidently changing their position frequently, according to the action of the current at its various stages of elevation, which appear to have been a powerful agent in their accumulation.

Sections of the river were taken at three points which exhibit ten feet for the greatest depth at two of the places, and eleven feet at the third.

The rock bottom of the river, on which a dam must be founded, will, therefore, probably be met with at not less than ten feet below the surface of the water. It is proposed to take the water from the river near the mouth of Jordan Creek, raising its surface ten feet with a dam, which will increase the whole fall to forty-eight feet, and reduce the amount of excavations for the canal.

The left bank of the Miami presents, at this point, a high bottom for the abutment of a dam. The river is three hundred and sixty feet wide at low water, being much narrower than at any point below. The bottom land on the right bank is also higher than at the other places, where sections were taken. It is, however, but fourteen feet high at the distance of eight hundred feet from the river, and would require an embankment or extension of the dam to that distance.

The length of a canal from the mouth of Jordan Creek to the high ridge, will be ninety two thousand two hundred and seventy feet. Average depth of cutting in that distance, above the level of the dam, 11.62 feet. A tunnel through the ridge would be eighteen hundred and seventeen feet long, entering the hill under a depth of about thirty six feet of earth. We have no precise data for estimating its expense, but the cost will fall much below that of an open cut, as the ground is in one place, for the distance of one hundred yards, more than eighty feet, and averages, throughout the whole distance, more than fifty feet above the level of the dam; an open cut would therefore require the removal of several hundred thousand cubic yards of earth, if the ridge should contain no rock. Indeed, the rock no where presents itself to view at the surface. The formation of the adjacent hills, however, leaves but little doubt of its existence; but, at what depth, or in what state, can only be ascertained by experiment; but, under all probable circumstances, the cost of a tunnel will fall much below that of an open cut.

From the outlet of the tunnel to the site of the workshops, the canal would be open a distance of two hundred and sixty-four feet, and the cutting would average fifteen feet above the level of the dam.

Estimate.

Excavation of 304,133.25 cubic yards of earth, averaging from 16 to 24 feet depth - - -		$ 74,063 50
Excavation of rock for tunnel, 1817 feet long, 13 by 11.36 feet, estimated as consisting of rock alone, 9932.7 cubic yards - - - -		40,000 00
Masonry.—Walls for forebays, races, and canal, including arches, 12,409.71 perches -		25,191 70
Wall at mouth of ravine, to shield the river bank from the washings of the tail races, 1,818.18 perches - -		3,636 36
Dam, 400 feet long, 20 feet high, of large stone, dressed, including covering and filling - -		29,000 00
Embankments, 800 feet long, each, 22,133.32 cubic yards - - - - - -		2,766 66
Head gates to canal, bridges over forebays and canal		597 92
Buildings and fixtures for machinery - -		137,556 86
Tools, machinery, and patterns -	14,522 00	
Miscellaneous articles - -	1,549 00	
		16,071 00
		$ 328,884 00
Contingent expenses, estimated at 10 per cent. -		32,888 40
Six hundred and forty acres of land, at $ 20 -		12,800 00
Aggregate,		$ 374,572 40

This site offers, in several respects, peculiar advantages. The extent and fertility of the adjacent country, and its proximity to Cincinnati, will assure to it a plentiful supply of provisions, and the command of all necessary supplies of materials and labor.

The navigation of the Ohio is free from many of the impediments which exist at higher points. The health of the place is comparatively good, and the volume of water afforded by the Miami, at its lowest stage, is abundant.

The highest known rise of the Ohio, at North Bend, is stated at 57 feet. The highest rise of the Miami, near Jordan Creek, is said to be 15 feet. These great rises, however, do not occur annually, and are said to last for only a short period. The whole fall obtained, with the aid of the dam, is 48 feet. The least efficient head of water being 4 feet, and 1 foot of the fall used in the descent of the canal, the works would not be stopped by a rise in the Ohio, until it reached the height of 43 feet, and that with the Miami at its lowest stage, (an occurrence by no means probable,) giving to the Miami a rise of only 3 feet above its extreme low stage; when the freshets occur in the Ohio, will permit the continuance of operations, till the rise of the latter equals 46 feet. If the Miami should rise to one third its greatest height, the works would not be stopped by a rise of 48 feet in the

Ohio. The elevation of the Miami to one-half of its greatest rise, would continue the operations with the Ohio at an elevation of 50 feet; and if the rises of the Miami and Ohio should be simultaneous, and proportionate to their respective greatest elevations, the power would be permanent.

From the best information that could be obtained, it appears that the usual height of the winter and spring freshets, is from 35 to 45 feet at Cincinnati; and that the water remains at above 40 feet elevation for about fifteen days annually. It is therefore probable that the interruption of the power by high water, will not constitute a serious objection to the site, if a dam can be erected to raise the surface of the Miami ten feet.

The hazards of a dam 20 feet high, across the Miami, a rapid and powerful stream, with an average fall of about 4 feet per mile, for some distance above and below, are not easily estimated. The point selected for its erection, is probably the best that can be found. Placing it further down the stream, where the right bank is lower, would not only increase the hazard of its loss, but would reduce the whole amount of fall, and increase the depth of cutting for the canal.

Placing it higher up will compel a resort to a river wall along the left bank, under a high bluff, for conveying the water down to Jordan Creek, where the canal would enter the bottom land.

The extreme rise of the Miami, near Jordan Creek, is said to be 15 feet. The high bottom, not now subject to overflow, is at the distance of about 800 feet from each abutment; and instead of embankments, it may be found indispensable to extend the dam, or build heavy walls of masonry for a part, or the whole of the distance, at an expense greatly beyond the sum estimated for a dam 400 feet long, with the embankments.

Several situations were examined on Licking river, Kentucky, within ten or twelve miles from its mouth. An abstract of the levellings taken at each of them is placed in the appendix; and, together with the sections of the ground, exhibited on the accompanying plans, will shew the height to which the rapids or falls, at those sites, are severally covered by the freshets of the Ohio, independent of the rises in the Licking, and render a particular description of them unnecessary. The only position below Falmouth, near the Forks of the river, at which an adequate or permanent power can be obtained by means of any dam, that it would be safe or perhaps practicable to erect, is at the mouth of Bowman's creek, twenty-three miles from the Ohio river. The highest rise of the Ohio, does not cover the rapids at this site.

We did not examine it, but, from the returns of the surveyor, who took the level, it appears that a fall of 14.5 feet may be obtained in the distance of 3¼ miles: and that it would be necessary to take a canal near two miles through a river bottom, that averages 31 feet high above low water, to where the fall could be employed. An Armory at a site so circumstanced, would probably cost above four hundred thousand dollars.

Site at Zanesville, Ohio.

The Muskingum river, as it approaches Zanesville, runs in a south-west direction, till it reaches the falls. In passing them, it changes to a southeasterly course, forming nearly a right angle in its progress to Slagoe's run, where it bends away in a more southerly direction. The town of Zanesville occupies the angle, formed by the river, stretching along its left bank, opposite and below the falls. Adjoining the lower part of the town, the river bank is narrow, affording barely sufficient space for the location of a canal and workshops. The second bank rises about 20 feet higher than the first, and affords a plat of about 20 acres, extending back a short distance, to the foot of the hills, at its eastern extremity, but gradually widening towards the northwest. Licking creek enters the Muskingum from the westward, in the bend of the river at the falls, and above the town of Putnam, which occupies the right bank of the river, extending downwards, opposite and below Zanesville. The falls are now the property of an Incorporated Company, who have erected a dam 5½ feet high, cut a canal for the supply of mills, &c. and sold portions of the water power on both sides of the river.

This Company has offered to the United States so much of the water as may be necessary for the uses of an Armory, and the entire control of the stream, when at a low stage, on the single condition that the Government construct a permanent stone dam and lock, for the passage of boats over the falls.

Should an extension of the establishment, at a future period, require all the water which the site affords, it will involve the necessity of purchasing the entire rights and privileges of the Company, which they offer at 80,000 dollars. The natural fall in the river, from the head of the rapids to Slagoe's run, a distance of 1300 yards, is nine and a half feet. It is proposed to erect a stone dam seven feet high, nearly in the place occupied by the Company's dam, take the water out at a point about sixty feet above Granger's Mills, and cut a canal from thence, through the town, to within 500 feet of Slagoe's run, a distance of 1056 yards. The canal will pass 1023 feet through rock, averaging 16.35 feet deep, with 12.66 feet of superincumbent earth. From the termination of the rock to the end of the canal, the sides will be walled, and the bottom flagged; the distance is 2145 feet, and average depth of earth 21.38 feet. From the dam to the site, the canal passes through the town of Zanesville, and requires to be walled on both sides, for the purpose of occupying a less width of ground, and providing against the accumulation of obstructions. From the first workshop, to the end of the canal, a wall on the side of the shops is indispensable, and the narrowness of the river bank, warrants the use of one on the opposite side, although the expense is increased, as will appear by a reference to the calculations, page 108.

The public spirited citizens of Zanesville, aware of the expense of cutting a canal through the town lots, from the great value of both land and buildings, have determined to furnish, free of expense to the

Government, all the ground necessary to be occupied by the canal, in its passage from the dam to the proposed site. The town authorities have also assumed the expense of bridging the streets and alleys wherever it may be requisite; therefore, the amount necessary for these objects is not embraced in our estimate. To render the abutment of the dam on the right bank more secure, and also to save the expense of constructing head gates, and a race for supplying them, it has been considered advisable to purchase out the mills and water rights on the west side of the river, and they are included in the estimate accordingly. The dwellings for workmen are omitted in the estimate, and are dispensed with, from motives of economy; all those who cannot be accommodated in the buildings now erected, and included in the purchase of the site, must reside in the town.

A list of the lands, amounting to $331\frac{35}{100}$ acres, with numerous dwellings and other buildings, marked Plan Z, No. 1, exhibits a description of the property to be purchased, including several coal banks, and the title bonds procured by the committee of the town, from nearly all the owners, assures to the Government the price to be paid for the same.

Plan Z, No. 2, shows the boundaries of the lands, and the location of the work shops.

Plan Z, No. 3, exhibits a profile and sections of the canal, at several points.

Estimate for Zanesville.

Excavation of earth, for canal, forebays, races, and river wall, 122,956.4 cubic yards of earth, averaging from three to twenty-two feet deep, - - - -	$29,001 75
Rock for canal, 6,161.4 cubic yards, averaging 16.72 feet depth, under 12.66 feet of earth, - - -	7,393 68
Walls for canal, forebays, races, flagging piers, arches, and river wall, 39,787.02 perches, - - -	79,950 04
Head gates to canal, and bridges over forebays and canal, - - - - - - - - - -	500 00
Dam and wing, 963 feet long, 7 feet high, of large dress'd stone, filling, covering, &c. - - -	26,000 00
Lock, 90 feet long, and 20 feet wide, - - -	5,000 00
Workshops and fixtures for machinery, - - -	48,910 49
Tools, machinery, and patterns, 14,522 Miscellaneous articles, - - 1,549 } - - -	16,071 00
	$212,826 96
Contingent expenses, estimated at 10 per cent. - -	21,282 69
$331\frac{35}{100}$ acres of land, and buildings of various descriptions, sufficient to quarter the officers and part of the workmen, - - - - - - - - -	70,864 00
Jackson's mills, valued at - - - - -	8,000 00
Aggregate,	$312,973 65

The whole fall obtained with a dam seven feet high, is sixteen and a half feet.

The great rise of the Muskingum, in 1817, just below the dam, is stated to have been 19.25 feet, while, at the lower bridge, it rose 23.166 feet. The fall in this distance is seven feet at low water, which gives more than three feet difference of level, at the time of highest water; and as the difference must be greater between the water above the dam, and the river at Slagoe's run, it may equal four feet, which is the least efficient head that will operate re-action wheels at high water, advantageously. Zanesville is 80 miles above the mouth of the Muskingum, by water, and 60 miles by land. The river is navigable for keel boats drawing 30 inches of water, for two months, and for those drawing 18 inches, eight or ten months in the year. The impediments to navigation from ice, may be considered to exist about two months, annually. Of the shoals, the rocks at Duncan's falls, 9 miles below Zanesville, are considered far the worst.

Levels were taken and profiles constructed, for the purpose of estimating the expense of using the waters of the Muskingum at a site below Putnam; but the cost of a dam across Licking Creek, a high river wall along the foot of the cliffs below the mouth of that stream, and its consequent insecurity, with the deep cutting and length of canal necessary to convey the water to the lower part of the town, where only a site could be procured on favorable terms, made the whole expense exceed the cost of the site below Zanesville, and caused the project to be relinquished. Plan P exhibits the profile of the ground, and sections of the canal and river wall.

Falls of Big Beaver, Pennsylvania.

These falls continue about five miles, from their commencement to the junction of the Beaver with the Ohio river, twenty-eight miles below Pittsburg. The whole descent is fifty-seven feet, at low water, in the two rivers. The highest rise, immediately at their junction is thirty five feet, leaving twenty-two feet fall that is above the height of any freshet that has occurred, and independent of any rise in the Beaver.

There are several advantageous sites along the falls, at which water power may be employed. The most desirable, as regards its position, is on the left bank of the river, and about two miles above its mouth. The power which it affords is ample, and a more favorable arrangement of the ground than it offers, for the erection of workshops and other buildings, could hardly be contrived. But the great elevation of the ground, for seven or eight hundred yards below the point where it would be proper to build a dam for the purposes of an armory, would render the use of a river wall or tunnel, to convey the water that distance, unavoidable; and either expedient was considered more objectionable, on the score of its insecurity and expense, than

any inconvenience that might attend a situation higher up the river, on account of its greater distance from the Ohio.

The next most favorable position is at the village of Brighton, near the mouth of Walnut river, on the right bank of the river, and three miles and a half from the Ohio. It has the command of a greater power; and, in some respects, has peculiar advantages, which, with the reasons before stated, give it a preference over the one below it.

The distance from the head of the falls to the mouth of Walnut run, is about a mile and a half, and the descent is twenty-two feet at low water. The highest rise of any freshet at the latter place, is 11.75 feet, leaving $10\frac{1}{4}$ feet difference of level, between the surface of low water above the falls and the highest rise of the river at the mouth of Walnut run. The Beaver is confined, at the head of the falls, and for some distance below, by a range of steep hills on its left, and a high and nearly level bed of rock on the opposite side, that terminates perpendicularly at the water's edge.

Descending from this point, the river makes a bend to the right, embracing in its course to the mouth of Walnut run, a wide and elevated plain, lying between it and the hills to its right. The village of Brighton is at the lower end of this plain, where it rises gradually from the river to the height of 40 feet above low water. The surface of the rock that forms the right bank of the river at the head of the falls, is about 31 feet above the low water at that place. Following the course of the river, downwards, it gradually declines in height; and at the distance of 500 yards, it disappears below the surface of the ground. From thence, to the site at Brighton, the ground presents an inclined plane towards the river; and for the greater part of the distance is sufficiently at command, as relates to the depth of cutting that may be required for a canal.

In the plan for this site, it is proposed to erect a stone dam, eight feet high, at the head of these falls, to take an open canal from above it, through the rock plane, and thence, nearly parallel to the course of the river, as far as Brighton, and to establish the workshops on the left bank of Walnut run. The difference of level between the top of the dam, and high water at the site, is 18.25 feet, which gives 16.6 feet, head and fall, that is employed on two overshot and two breast wheels, placed above the level of the highest freshets.

The dam will rest on a level rock foundation, about eighteen inches below the surface of low water; and will have the solid rock, on both sides of the river, for its abutments. A waste way, or weir, may be opened through the rock, from the canal to the river, at any point that may be preferred. We have placed it about 2,000 feet below the head of the canal, where the surface of the rock is about eight feet above the highest rise of the river, immediately opposite, and four feet above the level of the dam. It is near seven times wider than the canal, and its position secures it from any hazard or inconvenience. Whatever may be the height of a freshet above the dam, nearly all the surplus water, supposing it to have free ingress into the canal, must be discharged over the weir, and the level of the wa-

ter in the canal below it can never rise two feet above its ordinary height; and, if necessary, or desirable, the water in the canal, near the workshops, may be kept, at all seasons, within a few inches of a uniform level.

Estimate of expense for an Armory at Brighton, on Big Beaver.

EXCAVATIONS.

Of earth, for forebays, races, &c. 16,960.53 cubic yards, at different depths, from three to twenty-six feet -	$3,275 91
For canal, 1236.3 cubic yards, two and two and a half feet deep, at six cents per cubic yard - - - -	74 17
15 619.8 cubic yards, 12 feet deep, at 17 cents per yard	2,655 36
27.042 cubic yards, 7 feet deep, at 10 cts. per cubic yard	2,704 20
19,447.69 cubic yards, 14 feet deep, at 19 cents per cubic yard - - - - - - - - - - -	3,695 06
Of rock for canal, 21,534 cubic yards, averaging 19.7 feet, at $1 10 per cubic yard - - -	23,687 40
245.3 cubic yards, 4.6 feet deep, under 7 feet depth of earth, at 90 cents per cubic yard - - - -	220 77
607.2 cubic yards, 8.2 feet deep, at 80 cents per cubic yard - - - - - - - - - -	485 76
948 cubic yards, 4 feet deep, at 60 cents per cubic yard	568 80

MASONRY.

For forebays, races, and side wall, 3,934.09 perches, at one dollar 68½ cents per perch - - - -	6,628 93
275.15 perches for flagging, at three dollars thirty-seven cents per perch - - - - - - - -	927 25
Walls for canal, 1369 perches, at one dollar 68½ cents per perch, - - - - - - - - - -	2,306 76
Stone dam, eight feet high, 520 feet long, water tight, stones of large dimensions, hammer dressed, including covering, and filling, and guard dam during its construction - - - - - - - -	13,031 39
Head gate - - - - - - - - - -	142 84
Two bridges over canal, at $100 each, and four over the forebays, at $25 each - - - - - -	300 00
Buildings, including officers' quarters, dwellings for workmen, offices, &c. workshops, with fixtures for the machinery complete - - - - - - - -	138,497 05
Tools and machinery, patterns, miscellaneous articles, &c. - - - - - - - - - -	16,071 00
	$215,272 65
Contingent expenses, estimated at ten per cent. -	21,527 26
1,356 acres of land, with water privileges, mills, &c. including Broadhead's claims, and settlers' rights	43,050 00
Aggregate	$279,849 91

The principal proprietor of the land which includes the site, declines selling a part, with the exclusive water right, for a less sum than is demanded for the whole tract. It is supposed that the title to a small portion of it, is disputed; but, both as regards its quantity, or situation, it is considered of no consequence to the site.

About fifty buildings are erected on the several tracts embraced in the estimate, including three grist mills, one saw mill, a forge, one two story stone dwelling house, and several frame dwelling houses. They would be of little or no use to an armory, except to accommodate the hands during the erection of the works. Those that are now worth any thing, will, ultimately, be in the way, and must be removed; the rest may be considered as useless. Stone coal abounds in the adjacent hills, but the veins which have been, hitherto, discovered, does not exceed two and an half, or three feet in thickness; the coal will, therefore, cost more, and is, probably, inferior to that of Pittsburg. In the estimate of the annual expenditure of an armory at this place, the coal is supposed to be brought from the Ohio river. In case a vein of four, or four and a half feet thick should be found near the river, within four or five miles above the dam, coal will not cost above two cents and a half, or three cents per bushel, delivered at the works. Provisions, and building materials, are abundant, and labor cheap. The quantity of water which the Beaver furnishes, at its lowest stage, probably exceeds 135 cubic feet per second; the estimate of its volume is made from data obtained at Pugh's mills, a mile and a half below Brighton. An armory, at Brighton, will require sixty-six cubic feet per second, with the head and fall of 16.6 feet on breast and overshot wheels, exclusive of the forge, which will be operated by a reaction wheel, below the others. It is more than probable, therefore, that the river will afford, at its lowest stage, at least twice the power that is required for an armory, without resorting to any portion of the fall, which is below the level of high water, except for the forge.

Keel boats navigate the Beaver as high up as Pugh's mills, within a mile and a half of the site at Brighton, about ten months in the year. Steam boats may ascend to the same place from two to four months in the year. The Beaver and Ohio are generally closed with ice from one to six weeks; both have been known to continue open all winter oftener than they have been closed for six weeks.

Plans B. Nos. 3, 4, 5, and 7, exhibit profile, and sections of canal, at Brighton; location of the buildings; plan and section of the dam; section of the river; and plan of O. Ormsby's lands.

Ohiopile Falls, of the Youghiogheny River.

Where the Youghiogheny enters the Gap of the northern range of Laurel-Hill Ridge, it makes a circuit of near two miles round a neck, or tongue of land on its right, about three-fourths of a mile in length, and from three to six hundred yards broad, that projects from the foot

of a mountain in its rear. At the upper side of this tongue, and near the extreme point of the mountain, is the commencement of the Ohiopile falls and rapids, which terminate at the lower side, opposite to the point at which they begin, and six hundred yards distant from it, in a straight line. The whole descent is 87½ feet; the highest rise of any known freshet, is ten feet above, and twenty feet below the falls; leaving sixty-seven feet fall, free from interruption by the highest freshets. The area of the neck exceeds a hundred acres, and its general surface is sufficiently uniform for all the purposes of a site. The ground, on its lower side, next the foot of the falls, is advantageously disposed in steps or benches, of sufficient width, and at convenient distances below each other, for the erection of buildings, and the successive application of the water to machinery, in any manner that may be desired. Forty feet of the whole fall, may thus be employed, at a trifling expense The bank then becomes steep, and nearly perpendicular, and the remaining part of the fall could not be conveniently used, without extensive excavations of the rock. To convey the water to this site, from above the falls, will require a canal of 700 yards in length; the first 400 yards passes through a strip of river bottom: the deepest cutting along the whole route is thirty feet, and occurs in passing a narrow ridge, near the middle of the neck, consisting principally, as is supposed, of rock. A dam four feet high, across the river, will be necessary to procure a depth of water, at the head of the canal, sufficient to prevent it from being choaked with ice, or obstructed by drift of any kind. The quantity of water which the river furnishes at this place, during an extreme dry season, is probably equal to its volume at Connelsville, fifteen miles below, where (estimating from data, obtained at one of the Iron Works, within six miles of that place) it appears to have been not less than eighty cubic feet per second, and perhaps exceeded one hundred cubic feet per second, during the uncommon drought, in 1823. The great fall, and the mode in which the water may be employed, at Ohiopile, renders the question concerning the difference of its volume, at the two places, one of very little consequence. In the following estimate, the rock is supposed to reach within four feet of the surface of the ground, from the point where the canal leaves the river bottom, to its termination near the work-shops.

ESTIMATES.

Excavations of earth, for canal, forebays, and races, 17,078 cubic yards, from 3 to 13 feet deep,	$2,747 60
Of rock, for canal, basin, forebays, and races, 8,660.2 cubic yards, from 3 to — feet deep,	9,157 62

MASONRY.

Walls; for the basin, forebays, races, and wier, 1478.7 perches, at $2 per perch - - - -	2957 40
Head gate, 17 feet high, - - - - -	187 84

Dam, 4 feet high	6300 00
Four bridges	175 00
61 buildings, including dwellings for officers and workmen, offices and workshops, with fixtures for machinery, &c.	147,330 51
Machinery and tools	14,522 00
Miscellaneous articles	1,549 00
	$184,926 97
Contingent expenses, estimated at 10 per cent.	18,492 69
640 acres of land, value not known, not to exceed $2 per acre	1,280 00
Aggregate	$204,699 66

If we regard the site at these falls, in reference to the security of the works that might be erected on it, the perfect command of its water power, and the cheapness with which it may be employed, it surpasses any that has come under our observation. An additional excavation of 10,500 cubic yards of earth, and 900 of rock, estimated to cost less than $3,000, would enlarge the canal sufficiently to convey the whole volume of the river to the works at low water, which would furnish three times the power requisite for the Armory, and still leave unemployed, a fall of more than twenty feet, that is altogether free from any interruption by freshets.

To these advantages are opposed its geographical position, and its want of convenient communications. Surrounded on all sides by mountains, the adjacent country but sparsely inhabited, and with the exception of fuel, (including stone coal) affording few or no resources for an Armory: it is without the means of water conveyance, and as yet, without roads. Connelsville, 15 miles distant by land, is the nearest point from whence boats descend the Youghiogheny, and from that place its navigation is irregular and precarious, and, it is believed, cannot be relied on more than two months in the year. Brownsville is the nearest point on the Monongahela, and is twenty-eight miles distant.

The national road passes within seven or eight miles of the falls, and a good road leading to it may be opened at a moderate expense per mile. After ascending the mountain, (10 or 1200 feet) the ground is sufficiently even and otherwise favorable.

Much of the supplies for the armory, including nearly all the provisions for the workmen, must be drawn from the neighborhood of Connelsville and Union Town; and if, to the cost of opening convenient roads, is added that of a permanent bridge over the Youghiogheny, at the falls, the site will no longer be conspicuous for its economy.

On the left bank of the river, near the head of the falls, is a site, in some respects preferable to the one just described; it would, perhaps, be still less expensive, and would communicate with the national

road, without the necessity of building a bridge over the Youghiogheny. It is doubtful, however, if the power which it affords might be sufficient. The fall is only thirty feet at low water, and terminates at a point, where the river is deep, and has but little descent for some distance below. It is, therefore, probable, that the freshets rise at that place to more than half the height of the whole fall, and reduce the power to less than one-fourth of that obtained at the lower side of the neck.

How far the weight of the preceding objections ought to be lessened by the probability of any future canal across the mountains, passing down the valley of the Youghiogheny river, is a consideration that does not properly come within the province that has been assigned to us.

We should present a very imperfect view of the relative advantages of the foregoing sites, were our examinations confined to the original cost of erecting the necessary buildings of an armory at each, and of applying the water power to its machinery. The difference in their annual expenditures will be far more important than that of their first cost, and, although it may not be practicable to show the whole, or even the greater part of the amount of these differences, yet there are several objects of yearly expenditure, iron, fuel, and transportation, in particular, of which the cost, in each instance, may be stated with sufficient accuracy to serve for a comparative estimate. It is seldom, and only to a small extent, that iron is made in the western country of equal quality to that from the Juniatta works, and wherever this is the case, the Juniatta iron regulates the price. The best iron made near the site on Harpeth river, costs more than the Juniatta iron may be delivered for, by contract, brought by the way of Pittsburg. The neighborhood of iron works to any of the sites we have examined, will, therefore, not lessen the cost of that material at the armory, whatever advantage the circumstance may offer as a resource against accident or delay in the regular supply from Pittsburg. The cost of its transportation, or an equivalent sum, must be paid at all the sites below that place.

The following statement will show the annual expense of fuel and transportation of 122½ tons from Pittsburgh, including the iron, and in order to present the whole question of the relative cost of the several sites at one view, the estimated cost of the armory at each, is recapitulated.

		Cost of the Armory.
Beaver, annual expense of fuel and transportation - - - - -	$2,693	$279,849
Zanesville do do	3,697	312,973
North Bend do do	4,974	374,572
Falls of Ohio, (Jeffersonville) do	5,922	321,184
(Louisville) do	5,922	505,067
Narrows of Harpeth do	8,087	357,940
Cypress Creek, (Alabama) do	8,764	232,365
Ohiopile Falls of the Youghiogheny river -	-	204,699

We have no means of estimating the cost of transportation, or of fuel, with correctness, at Ohiopile: the latter item, however, would probably cost less than at Beaver. Stone coal is estimated at eight cents the bushel, at North Bend, and ten cents, at the Falls of Ohio: it has been sold for less at Louisville; but it is ascertained that a regular supply of Pittsburg or Wheeling coal cannot be obtained at either place, for less than the estimated price. That procured from Eagle creek, and other points much below Wheeling, is of inferior quality, and would not be used. It appears, from the above exhibit, that the annual expenditure at the sites south of Zanesville, for the items therein enumerated, increase to an extent that is sufficient to exclude them from further consideration, as regards their comparative advantages, merely as manufacturing establishments; and they would, probably, constitute but a small part of the annual excess of expenditure at those sites. The cost of labor will comprise near two-thirds the amount of the whole yearly disbursements at an armory: and it must successively increase at Louisville, Harpeth, and Cypress in Alabama. The present prices of labor at those places can be of little or no avail, for the purpose of comparison between them and the sites of Cincinnati, Zanesville, Beaver, and Ohiopile. The description of mechanics that are employed at an armory cannot, certainly, at this time, be obtained at Florence in Alabama, and must be led to emigrate thither by the inducement of high wages. Nor is it at all probable, that they would be found in sufficient numbers near Nashville. At Springfield and Harper's Ferry, an expert workman may earn from two to three dollars a day; which is evidence that, even at those armories, the number of first rate workmen is not equal to the demand for their services, or competition would long since have reduced the rates of their labor. The high price of provisions at Harpeth and Florence, compared with prices at, and every where above Cincinnati, would, unconnected with any other cause, produce a much greater excess of expenditure at those places, than what has been already shown must exist. The circumstance before stated, that Juniatta iron can be carried to Nashville as cheap, or cheaper than it is manufactured in that neighborhood, is strongly presumptive of the correctness of this assertion; and another and similar circumstance may be stated in its confirmation. The iron works near Harpeth have the advantage of good water power, fuel in abundance, and ore of an excellent quality, and in large quantities. The iron works on the waters of the Monongahela and Youghiogheny rivers, labor under a comparative want of fuel for smelting the ore; and provisions, in their immediate neighborhood, are much dearer than at any point on the Ohio river, above Louisville. Iron from those furnaces is taken to Pittsburg in the pig: it is there refined, rolled, and then manufactured into nails, for the same price at which bar iron is sold at the works near Nashville. Unless the profits in the latter case are very extravagant, the inference must be highly unfavorable, as regards the price of labor, and other causes of expense, at a manufacturing establishment on the Harpeth; and which must operate extensively at an

armory, where two hundred mechanics are employed, besides fifty or sixty common laborers. And, so far as the price of provisions may influence that of labor, the position near Florence certainly offers no advantage, in point of economy, over that on Harpeth river.

The great commercial advantages that are united at the Falls of the Ohio, and the unequalled command which that position affords of water communication with all parts of the Western country, have contributed more than the character of its water power, to give repute and value to its manufacturing advantages. The difficulty and danger inseparable from the location of works immediately on the bank of a large river, subject to equal fluctuations in its volume with the Ohio, and rising to the height of thirty-five and sixty feet above its lowest stage, must be evident to all who are familiar with the use of water power. And, when, to the expense and hazard attending the occupation of a site so circumstanced, is added the certainty of an annual interruption to the power, of six or eight weeks continuance, and a liability to a longer interruption, the objections to its employment at an armory appear to us to be conclusive and unanswerable. The advantages of the site at North Bend have been mentioned: as relates to the price of labor and provisions, they are, perhaps, equal to those of any site that has been examined. From its vicinity to Cincinnati, its resources, in a general point of view, are superior to most of them; and, in its command of the navigation of the Ohio, it is only inferior to Louisville. The cost of the water power, and the insecurity of the dam across the Miami, more particularly the latter, form the principal objections to it.

The water power at Zanesville would never be entirely interrupted, nor seriously incommoded for more than a few days in a whole season; and may therefore be considered permanent. The dam across the Muskingum may be made secure; and, it is believed, that the river affords water enough at all times to extend the operations of an armory to the production of 50,000 muskets per annum: and as the greater part of the workmen might reside in the town, without much inconvenience, the site is sufficiently spacious to receive the additional number of buildings that might be required for other purposes. To these advantages, it unites those of fuel in abundance; provisions at the lowest rates; a number of manufacturing establishments now in operation; and convenient boat navigation to the Ohio river, nine or ten months in the year.

In estimating the advantages of a place in reference to it, as a site for an armory, it is certainly proper to consider those resources that would be brought into activity by the stimulus they would naturally receive from the annual disbursements of an armory in the vicinity. At some of the sites that have been enumerated, the effect would be necessarily inconsiderable. But the country around Zanesville produces raw materials of several kinds, and iron ore among the rest; and a great amount of unemployed water power is found within a few miles. At Duncan's falls the power is equally great with that adjoining the town, and sufficiently constant to be valuable for manufac-

turing purposes; and that on Licking Creek is never interrupted. Combining with its present advantages so many circumstances favorable to its future industry, this place offers many and strong considerations in favor of its adoption as a site for a national armory. The objections to it are chiefly relative, and arise from comparing it with a more perfect water power, and a more convenient, and less expensive site. The description given of the position on Big Beaver, Pennsylvania, leaves but little to say on the character of its water power. The perfect command of the water at all times, the more convenient manner of applying it to the wheels, which the fall at that site allows; its entire freedom from interruption by drought or freshets, and the security it offers to the whole establishment of an armory, from the dam to the last work-shop, give it decided advantages in these respects, over any water power that has been examined, with the single exception of that of Ohiopile. It has a further advantage over that at Zanesville, in the greater number, and more convenient arrangement of the buildings; greater economy in the first cost, and subsequent annual expense; and the last that will require to be stated, is the superior healthiness of its situation. Comparing it with Ohiopile, it is apparent, that the advantages which would accrue to the armory from its position on the Ohio river, from its vicinity to, and consequent command of, the resources afforded by the town of Pittsburg, more than compensate for the additional cost of its water power.

Steam Power.

The peculiar, if not the most prominent advantage of steam power, in a general point of view, is the liberty it affords of employing it wherever a power may be required, and fuel is at command. This independence of locality, however, is confined within certain limits, as regards its practical utility. It requires a complex machine in its production, liable to accidents and interruptions from causes that are also peculiar to it; which, indeed, are of little consequence, where the necessary facilities exist for the repair or renewal of any of its various parts that may be injured or destroyed; but which, under less favorable circumstances, in these respects, may be attended with serious inconvenience and delay. Its convenience, and even economy, therefore, does not depend exclusively on the cheapness of fuel. And, as the town of Pittsburg unites nearly all advantages that are either essential, or may contribute to its economical employments, and to an extent, equal, perhaps, to what they are found separately elsewhere; the use of steam power will be considered as confined to that place, while viewing an armory merely as a manufacturing establishment.

The capability of steam to propel machinery of any kind, or to any particular extent, no longer offers a subject for inquiry. The question at present is confined to its economy, and the advantages at-

tending its use at a particular place. The first cost of steam engines, and their annual expense, does not increase or diminish in proportion to the size of each engine: a considerable part of the expense is that of attendance, which is equal in every case, at least within those limits that concern the present inquiry. The economy of steam, compared with water power, will, therefore, mainly depend on the number of engines that are to be employed. For all purposes that require, or will admit a concentration of the power, a single engine might be fully competent; and employed at Pittsburg, would be cheaper than almost any water power. But the power required at an Armory, is only employed as auxiliary to the labor of a large number of mechanics; and the nature and necessary distribution of the work to be performed by them, render a considerable division of the power indispensable to the convenience and economy of such an establishment.

It is satisfactorily ascertained that three engines or wheels will be indispensable; and to make the power, as it ought to be, subservient to the most advantageous arrangement of the work, will require the use of at least four engines or water wheels in all cases.

The following estimate will show the probable cost of an armory near Pittsburgh, with the first cost of an adequate steam power, as well as its annual expense.

Estimate.

Buildings, including officers' quarters; dwellings for the workmen, coal and engine houses, work-shops with fixtures, for machinery, &c. - -	$140,598 51
Machinery, tools, patterns, &c. - - -	14,522 00
Miscellaneous articles - - - - -	1,459 00
Four steam engines, complete, erected and ready for operation, (appendix, statement E.) - -	14,492 00
Add for contingencies 10 per cent. - -	17,107 15
To which may be added the capital necessary to renew the wearing parts of the engines and render the power permanent (not included in the estimate of annual expenses) - - - -	5,811 00
640 acres of land, at $50 per acre - - -	32,000 00
Aggregate,	$225,989 66
Estimated annual expense of four engines, including fuel, repairs, incidental expenses, and hire of four engineers, (statement F.) - - -	$3,631 20

The foregoing estimate of the engines is made conformable to present Pittsburg prices.

The engines are constructed on the plan of high pressure, capable of operating with sixty pounds to the inch; but of sufficient dimensions to propel all the machinery, at a pressure of thirty pounds, or less, to an inch.

We have been cautious in limiting the pressure of the steam to a less portion of the resisting force of the boilers than is found necessary, or any where practised with engines of this description. In what concerns their safety from the force of the steam, we are satisfied that such as are proposed to be employed in the estimate, will be accompanied with no greater hazard than those usually constructed to operate with a pressure of seven pounds to the inch. And, independent of their greater economy, we believe them preferable, on several accounts; they are more simple in their construction, easily attended, less liable to get out of order, and the several parts more easily repaired and replaced when injured or worn out. The accidents that have occurred on board of steam boats afford but little ground for the apprehension of similar misfortunes on shore; the use of steam in those boats is necessarily accompanied by many, and frequently by almost every circumstance of disadvantage to the safety of the engines. And when it is considered that an engine in a manufacturing establishment is never exposed to equal and not often to similar, causes of injury or hazard; that it is fixed, and not liable to be injured by accidents or movements of any kind that are extraneous to it; that the force of the steam, compared with the strength of the engine, will be moderate, and nearly uniform; we can perceive no valid objection to its employment at an armory.

The site which has been selected, in case the use of steam power should be adopted, is about a mile above the United States' arsenal on the Alleghany river, and three miles and a half from Pittsburgh. The ground is in every respect favorable, and includes several hundred acres of coal land. The arsenal will afford a convenient depot for the arms, and save the expense of erecting a building for that purpose.

The following statement exhibits the cost of an Armory at Pittsburg, and at Brighton: with the annual expense required for the manufacture of 12,000 muskets at each, exclusive of labor.

PITTSBURG.

Cost of the site, with buildings, fixtures, including steam engines, - - - - -		$225,989 00
Annual expense of the steam power,	$3,631 00	
Materials, (appendix, statement A.) -	31,149 70	
Miscellaneous expenditures, (statement C. appendix,)	2,395 00	
Total annual expenditure, exclusive of labor,		37,175 70

BEAVER.

Cost of the site, with buildings, fixtures, &c.		279,849 00
Annual cost of materials, including fuel, transportation, &c. (appendix A.)	$32,127 00	
Miscellaneous expenses, including repairs to the water works, (appendix statement C.)	3,487 00	
Total annual expense, exclusive of labor,		35,614 00

If these amounts are reduced to the same denominations, the difference in the expense of an Armory at either place, will appear trifling. The inconvenience to the site at Beaver, of its greater distance from Pittsburg, is embraced, for the most part, in the estimated additional cost of fuel and transportation. Under circumstances so nearly equal as regards their situation, and where both the steam and water power, are as free from any characteristic inconvenience, as would probably exist at any two points that could be named: it appears that a preference for either, must depend chiefly on the degree of comparative insecurity, and of occasional interruption, that may be attributed to the use of steam. The total exemption from all hazard to the buildings, and the workmen, that is secured to an establishment at Brighton on the Beaver, induce us to prefer the water power at that place.

The extent of the Armory which it is proposed to establish in the Western country, is not designated in the act of Congress; and although a power, sufficient for the manufacture of 12,000 muskets, has been taken as a standard in our estimates, it might be deemed expedient, and may be contemplated to extend its operations to the production of 24,000. In this case, it would be necessary to increase the number of workshops, and to repeat the divisions of the power; four additional water wheels or engines would be required, and consequently the annual expense of the steam power would be doubled: while the whole cost of enlarging the canal at Beaver, with the necessary walls, forebays, races, &c. for the additional water works, would not exceed $19,000; and the site at Brighton would have a decided advantage on the score of economy, with the volume of water now furnished by the Beaver at that place. But it would be unsafe to rely on its furnishing more than 135 cubic feet per second; and, in the event of a navigable canal between Lake Erie and the Ohio, passing along the Valley of Beaver river; its volume would probably be insufficient during a dry season, for the supply of the canal, and for the manufacture of 24,000 muskets; and on the hypothesis of extending the operations of the Armory to the production of that number, the site should be rejected. Of the likelihood of both or either of these events occurring, we possess, of course, no means of forming a judgment; and have therefore confined ourselves to stating the extent of the preference, to which we think the site is entitled, with those circumstances which might eventually render it objectionable. Another, and very different, view may be taken of the subject. The muskets are now chiefly manufactured complete in all their parts, at the National Armories: and our estimates have been based upon the suppostion, that the same system will be continued in the Western Armory. It is believed, however, that the cheapest method of fabricating small arms, is to contract with individuals for the greater portion of the component parts, and to be received, inspected, put together, and finished, at the public Armory, where all the machinery and hands required for performing the entire work, are in operation in the manufacture of a limited proportion of the whole

annual amount to be produced. This mode would enable an Armory to command the whole manufacturing resources of the country around it, and ensures the same degree of perfection and uniformity that would result from having all the parts made at that establishment.

The power required for the manufacture of 12,000 muskets per annum, would operate the necessary machinery for making 8000, and such other machinery as would be required for putting together and finishing 10,000; supposing the component parts to be made by contract, the estimated additional expense, either at Pittsburg or Beaver, would be $6000, including the cost of a workshop, with the necessary additions and alterations to the machinery and fixtures.

If the whole power, embraced in the preceding estimates, for the manufacture of 12000 muskets, were employed exclusively in stocking and finishing the parts of the muskets made by contract, it would be sufficient to complete 38,000 stands per annum, at an additional expense of $26,000, in buildings, fixtures, tools, and necessary alterations; and, in case of emergency, the number might be increased to 42,000. This arrangement would also lessen the divisions of the power, and two water wheels, or engines, would suffice. An armory manufacturing 12,000 muskets, annually, or only 8000, and finishing 10,000, might, therefore, continue to perform the same operations, and be extended so as to produce 50,000, or 56,000 per annum, by employing two additional steam engines at Pittsburg. At Brighton, the additional expense would be still less than that before stated, for the entire manufacture of 24,000 muskets; and to whatever extent the system of contracting for the component parts of the muskets might be carried within those limits, the comparative economy of the water power at that site would be proportionately increased, by the difference in the transportation of the parts of the muskets, and that of the raw materials; and by the difference at that place and Pittsburg, in the cost of nearly all the fuel required in their fabrication. These advantages, however, rest necessarily on the supposition, that the volume of water in the Beaver will be at the command of the armory; otherwise, the power it will afford must be considered as limited to the manufacture of 12.000 stands per annum, or an equivalent number manufactured and finished, in case any of the parts are made by contract.

It is evident, that the important advantage of thus extending the operations of an armory, and at a short notice, to the production of any given number of arms, can only be obtained by locating it in the vicinity of a place possessing capital, and the command of extensive water or steam power. It is certainly unnecessary to give a detailed account of the manufacturing resources of Pittsburg, for the purpose of comparing them, at this time, with those of any other place in the Western country. It may be proper to mention, however, that there are fourteen steam engines, from 20 to 80 horse power each, now in operation, either in the town or its immediate neighborhood—two of which were erected during the last season. Four of them are em-

ployed in forging, rolling, and slitting iron; three of these are of 80 horse power, and one of 40. Two others are about going into operation for different iron works. There are also two manufactories of steam engines, besides several establishments, that are more or less extensively engaged in the working up of iron and other metals into various objects of commerce. The power actually employed in these and other operations carried on by steam, exceeds that of the whole volume of the Muskingum at low water, with the head of eight feet.

A great advantage attending the use of steam power to a private manufacturer, consists in the small capital required at the outset, while the annual expenses are paid from the profits of the work, as they accrue. An individual, with a capital of only 5,000 dollars vested in the first cost of the power, actually employs one of which the present purchase is worth 20,000 or 25,000 dollars, even at Pittsburg; and more elsewhere, in proportion to the additional cost of fuel. This cause, perhaps, more than any other, enables steam to compete successfully with water power, for ordinary manufacturing purposes, even where its whole purchase is considerably greater, and both employed at the same place.

Notwithstanding this circumstance can have no weight in comparing the relative expense of steam and water power at a National Armory, yet, the great facility it affords to individual skill and industry, must be considered as assuring almost unlimited resources to such an establishment in the neighborhood of Pittsburg, where iron and fuel are cheaper than at any other place in the Western country.

We do not perceive any reasons of a military nature, that can materially affect the relative value of the different sites, in consequence of their respective distances from the points at which the consumption of arms would probably occur in time of war.

To consider the relations of an Armory in the same light with those of a Magazine or an Arsenal, we think would be an error. The means of production, being the principal requisite for the one; and those of conveyance, for the others. Even as regards the certain and regular supply of arms to troops that are in the field, the utility of its position may obviously depend much less on the shortness of its distance than on circmmstances which may facilitate or retard its operations.

If we compare the communications of Pittsburg and Beaver with those of the sites below, the difference will be found to consist, more in the distance than in the duration of their interruptions. This difference, however, is definite, or at least confined within certain limits, and the balance of the arms manufactured during that period, may be disposed of immediately after. If the probable interruptions or delays to the progress of the works are compared, the disparity must be considerable. The healthiness of the country around Pittsburg, and its constant command of all the materials and labor that is either permanently or occasionally required at an Armory, leave no room for any unfavorable anticipations in these respects.

But its most essential advantage, is in its manufacturing establishments and other resources, which would secure to the Government, in case of emergency, the means of promptly extending the operations of an Armory to the production of almost any required number of arms. And in all material respects, the position at Beaver is considered as commanding the resources of Pittsburg.

By a comparison of the cost of materials and fuel, used in the manufacture of the musket, at Springfield, Mass. and the probable cost at Beaver, we are satisfied that it may be manufactured at the latter place, or at Pittsburg, for more than 50 cents less than at Springfield, in 1825, in which year the musket cost less than at any former period.

This difference between the Eastern and the proposed Western Armories, in the actual and estimated cost of the musket, is probably less than would exist.

All which is respectfully submitted.

W. McREE,
ROSWELL LEE,
G. W. TALCOTT.

PHILADELPHIA, *January 12th*, 1825.

REMARKS.

It will be observed, that the cost of excavating earth for the tail-races, &c. at the workshops, is stated in the estimates, at less than the cost of other excavations from corresponding depths.

This is owing to the situation of the races, which enables the earth, for a considerable distance, to be removed horizontally without taking it to the surface of the ground above.

The cost of the perch of masonry depends considerably on the distance to which the materials are to be transported. At Louisville, the carriage alone, amounts to one dollar per perch. In computing the quantities of masonry for walls, the perch is estimated as containing 24.75 cubic feet.

ADDITIONAL REMARKS.

The wages of the Armorers at Springfield, will average about thirty-four dollars per month—board is two dollars per week: in all cases, the workmen find themselves; therefore, the wages paid by government, includes board, washing, &c. In some instances, a first-rate hand, with great industry, will make two dollars per day.

One hundred tons of iron is the quantity put down in the estimates, for making 12,000 muskets. This leaves a deficiency of twenty tons. The quantity that will be made from the scraps, borings, turnings, &c. is estimated at thirty tons, which makes up the deficiency, leaving ten tons for machinery and tools, waste, &c.

If there is any deficiency in the estimated quantity of stock, it is in the steel; but if that is of the best quality, and the scraps and worn out files are worked, the quantity will be sufficient for 12,000 muskets.

List of Plans and Papers referred to in the Report.

Marks.	
Plan C.	Plan and section of a canal on Cypress creek, near Florence, Alabama.
Map H.	No. 1. Survey of the Narrows of Harpeth river, Tennessee.
Plan H.	No. 2. Plan and section of canal at the Narrows of Harpeth river.
Do. S. & L.	No. 1. Plans and profiles, No. 1 and 2, of canals at Louisville, Kentucky, Falls of Ohio.
	No. 2. Sections of canals on profiles No. 1 and 2, above and below Shippingport, Falls of Ohio.
	No. 3. Embankment for canal between Louisville, and Shippingport.
	No. 4. Copy of L. Baldwin's profile of a canal at the Falls of Ohio.
	No. 5. Map of the Falls of Ohio.
Plan L. 2.	Plan, profile, and sections, of canal, between Louisville and Shippingport, second project.
Plan J.	No. 1. Plan and profile of canal at Jeffersonville, Indiana, Falls of Ohio.
	No. 2. Sections of canal at Jeffersonville.
Map N.	Route of canal from the Great Miami river, to the Ohio river at the North Bend.
Plan N.	Profile and section of canal and tunnel at North Bend.
Map T.	No. 1. Map of Licking River, Kentucky, from its mouth to Cruizer's Creek.
	No. 2. Map and profile of ground, at Three Mile Ripple of the Licking River.
	No. 3. Map and profile of ground at Six Mile Ripple of the Licking River.
	No. 4. Map and profile of ground from Six Mile to Dedman's Ripple on Licking River.
	No. 5. Map and profile of ground from Cruizer's Creek to Bowman's Creek, Licking River.
Plan T.	No. 6. Plan, profile and sections of canal from Cruizer's to Bowman's Creek, Licking River, Kentucky.
Plan Z.	No. 1. Plan of canal at Zanesville, and description of property included in the proposed site, with prices of the same.
	No. 2. Exhibiting the boundaries of lands, and location of the workshops at Zanesville.
	No. 3. Profile and sections of canal at Zanesville.
	No. 4. Profile of the Falls of Muskingum at Zanesville, and Duncan's Falls.
Plan P.	Profile of canal at Putnam, opposite Zanesville.

Profile of canal on the right bank of Licking Creek, Ohio.

PLAN B. No. 1. Canal at Beaver, profile, No. 1, and profile of Beaver river from the upper falls to Brighton.
No. 2. Canal at Beaver and profile No. 2.
No. 3. Canal and falls of Big Beaver and profile No. 3.
No. 4. Location of buildings at Brighton on the Big Beaver river, Pennsylvania.
No. 5. Plan and section of dam and section of the Big Beaver river, at the upper falls.
No. 6. Sections of the canal used for supplying the mills of the lower falls of Big Beaver.
No. 7. Plan of Ormsby's lands at Brighton, and opposite, with prices.

PLAN O. Profile of canal at Ohiopile falls on the Youghiogheny.

Survey of the Alleghany river above the United States' arsenal at Pittsburg.

Explanation of the tables.

Table C No. 1, exhibits the amount and cost of excavation and masonry for forebays and races for the site at Cypress creek, near Florence, Alabama.

Table M No. 2, column C, shews the expense of buildings and fixtures at the above site.

Table H No. 1, exhibits the quantity and cost of excavation and masonry for forebays, races, and river wall, at the site at Harpeth Narrows, in Tennessee.

Table H No. 2, shews the quantity and expense of buildings and fixtures for the above site.

Table S No. 1, shews the quantity and expense of excavations and masonry for forebays, races, and river wall, at the site below Shippingport, falls of Ohio.

Table M No. 2, column S, shews the expense of buildings and fixtures.

Table L No. 1, shews the quantity and expense of excavations and masonry for forebays, races, and river wall, at the site above Shippingport, near Tarascon's mills. The quantity and expense of buildings and fixtures are the same as at the site below Shippingport.

Table J No. 1, exhibits the quantity and cost of excavations and masonry for forebays, races, and river wall, at the site below Jeffersonville, in Indiana, falls of Ohio.

Table M No. 2, column J, shews the expense for buildings and fixtures.

Table N No. 1, exhibits the quantity and expense of excavations and masonry for forebays, races, and river wall, for the site at North Bend, Ohio.

Table M No 2, column N, shews the expense of buildings and fixtures at the above site.

Table T exhibits the quantity and cost of excavations and masonry for forebays, races, and side walls, for the site on Licking river, near Bowman's creek, Kentucky.

Table M No. 2, column T, shews the expense of buildings and fixtures for the above site.

Table Z No. 1, exhibits the quantity and cost of excavations and masonry for forebays, races, and river wall, for the site at Zanesville, Ohio.

Table Z No. 2, shews the quantity of materials and expense of buildings and fixtures for the above site.

Table B. No. 1 exhibits the quantity and cost of the excavations, and masonry for forebays, and races, for the site at the falls of Big Beaver creek, Pennsylvania.

Table B No. 2, shews the quantity of materials and cost of buildings and fixtures at the above site.

Table O No. 1, exhibits the quantity and cost of the excavations and masonry for forebays and races, for the site at Ohiopile falls, on Youghiogheny river, Pennsylvania.

Having no statement of prices from that vicinity, the buildings and fixtures are taken at the Beaver prices, with the addition of six per cent.

Table marked M No. 1, exhibits the estimated quantity of materials necessary for the several buildings; one eighth is added to the lumber and brick, for waste, &c.

Table P exhibits the prices of building materials, and other articles, as obtained from respectable sources, the vouchers for which will be found in the papers for each site, marked P.

Table P No 1, showing the quantity of materials, and cost of buildings, fixtures, &c. at Pittsburgh, Pennsylvania.

APPENDIX.

Pugh's mills are situated on the Big Beaver, at Sharon, one mile and a half below Brighton; they have seven water wheels, which are supplied by a canal 960 yards long. The whole of these works, with the exception of the saw mill, and, also, of the oil mill, (as it was understood at the time of our experiments,) continued to operate as usual during the driest part of the season in 1822, when the river was lower than at any former period, within recollection. The quantity of water which the rest of the works employed, was accordingly measured, and found to be sixty-seven cubit feet per second. It was subsequently asserted, that the oil mill had also continued to perform its ordinary work, at the same time with the rest, which would increase the actual quantity flowing into the canal to 85 cubic feet per second. The dam at these mills does not extend entirely across the river, and was the cause of the saw mill being stopped; as the surface of the river could not be raised sufficiently high to throw the necessary quantity into the canal; and, according to the unanimous testimony of all who were questioned, (among whom were several experienced millwrights,) the volume of the river was estimated to be three times that in the canal. Admitting an error in judgment, to the extent of one half, in relation to the quantity in the river, opposite the canal, and omitting to include the quantity employed by the oil mill, will make the whole volume of the river equal to 135 cubic feet per second; the quantity first stated. To ascertain the quantity of water used at these works, that portion of the canal was selected where its dimensions were most uniform, and its course nearly straight. The velocity of the water, while the mills were in operation, was measured with great care; the descent of the surface, and area of sections, at the several stations, were determined as nearly as circumstances would permit.

Table of the greatest observed surface velocities of the current in the Canal, at Pugh's Mills, on Big Beaver; the corresponding mean velocities of the whole volume of water; the area of the mean transverse sections of the several stations; and the quantity of water flowing in the Canal at that time; the gates of the Oil Mill and Saw Mill being shut when the experiments were made.

STATIONS. From	STATIONS. To	Distance between the respective stations.	Least time occupied by the float in passing the respective stations.	Greatest observed surface velocity per second.	Mean velocity, deduced from the surface velocity.	Area of the mean transverse section between the respective stations, in square ft	Quantity of water deduced from each experiment, in cubic feet, per second.
1	2	66 feet	32	24.75	not computed		
2	3	66 feet	32	24.75	not computed		
1	3	132 feet	64	24.75	20.1427	40.1128	67.3585
3	4	66 feet	34	not computed	not computed		
4	5	66 feet	33	24 inches	19.471	44.1123	71.57
4	6	132 feet	69	22.95	18.5389	44.072	68.087
5	6	66 feet	36	- - -	17.9834	45.0137	67.59

Number of each station.	Area of the transverse section of the canal, at each station, in square feet.	Perimiter of the section in contact with the water, in feet.
1	40.61721	20.43
2	40.030	20.56
3	39.738	20.94
4	42.009	20.80
5	46.215	22.89
6	43.991	21.78

From station four to five, the volocity was the greatest, compared with the area of their transverse sections, and, therefore, gives the greatest number of cubic feet per second. But, passing the third station, the difference in the areas of the several transverse sections, increase considerably, while the area at the sections at first, second, and third stations, are nearly equal, and the observed surface velocities between them were uniform. The quantity of water flowing in the canal, as deduced from the experiments made at those stations, are therefore considered as being the most correct.

An attempt was, also, made, to determine the volume of running water, by measuring the descent of its surface, which gave 90 feet per second, or near 19 cubic feet more than the greatest amount derived from the surface velocity. But several causes interfered to destroy confidence in the result. In order to obtain a sufficient descent, to lessen the consequences of any error in the levelling, it was necessary to include a portion of the canal, where its dimensions varied, and where the velocity was, consequently, accellerated, or retarded, in a corresponding degree. After all, the whole descent was only 1¾ inches; and the means employed, with which to measure from the surface of the water, were too inaccurate to be relied on for such an operation; an error, hardly exceeding the 10th of an inch, at each end of the line, would occasion a difference equal to that stated above. It was understood that the saw mill and oil mill had been stopped, for want of water, in 1822; the gates of both were, therefore, shut at the time the experiments were made. It has since been asserted, however, by those who had the management of the works, that the oil mill was never interrupted, during the lowest stage of the river, by that cause. If this statement is correct, the volume of water conveyed in the canal, as determined by the experiments, should be increased by the quantity required to operate the oil mill; which, computing from the head above the apertures at the wheels, and the area of the aperture, is found to be 11.4 cubic feet per second, making the necessary deduction for the contraction of the column of water after it issues, and the whole quantity will then amount to 78.7 cubic feet per second. It is the opinion of those well qualified to judge, and who have had daily opportunities to observe and compare the volume of water in the canal, with that of the river at its side, that the quantity in the canal, at a low stage of water, in ordinary seasons, does not exceed one eighth the whole volume of the river; and that, during the extreme low state of the river, in 1822, they believe the canal to have contained about one third of that in the river. According to these data, it would appear that the whole quantity supplied by the river, during its lowest stage, in 1822, was 236 cubic feet per second.

But, if we exclude the oil mill altogether, and suppose the quantity of water in the Beaver river to have been equal to the quantity employed at Pugh's works as determined by the preceding experiments, the whole volume of the Beaver must then have been equal to 134 or 135 cubic feet per second.

Table of the Quantity of Water and Power employed at Springfield.

No.	Kind of Wheel in use.	Whole quantity of water which issues on the wheel, expressed in cubic feet.	Whole effective head of water, or half the height of the column which issues on the wheel, added to the fall after it has issued, and before leaving the wheel, expressed in feet.	Measure of the power, or the whole effective head, multiplied into the whole quantity of water.
1	Breast	16.58	8.15	135.26
2	Tub	18.55	4.28	79.60
3	Tub	16.88	4.16	70.32
4	Tub	20.69	4.00	82.97
5	Tub	8.99	3.46	31.19
6	Tub	12.33	3.73	46.13
7	Undershot	22 76	5.26	119.73
8	Breast	4.61	8.81	40.66
9	Undershot	13.00	2.95	38.47
10	Breast	1.55	5.14	8.01
11	Tub	10 62	2.51	26.78
12	Breast	2.88	4.86	14.04
13	Low breast	5.94	7.46	44.36
14	Breast	4.81	6.62	31.92
15	Tub	13.95	2.35	32.81
16	Tub	15.90	2.83	45.02
17	Undershot	15.70	2.90	45.64
18	Breast	2.98	5.96	17.81
19	Undershot	5.28	3.46	18.31
20	Tub	16.71	2.74	45.91
21	Undershot	20 44	3.69	75.61
22	Tub	14.68	2.76	40.61
23	Tub	14.89	2.85	42.49
24	Undershot	60 57	3.35	203.08
25	Tub	9.36	2.15	20.18
26	Breast	1.59	6.26	9.85
27	Tub	7.32	2.17	15.93
		359.56		1,382.69
		23.89		
		335.67		
Deduct for wheels, No. 10, 12, 18, 23, and 26, being not indispensable for the operations performed by them, and are supernumerary				92.
				1.2,9069

The foregoing Table exhibits the quantity and power of the water employed, computing, according to the laws of gravity, from the dimensions of the several apertures at the wheels, and the mean height of the column of water issuing through each, without considering the influence of those causes which are known to operate in practice, and vary the results.

The trifling velocity of the spouting water renders the obstructions to its motion from resistance of the air too inconsiderable to merit particular attention as regards the objects of the present investigation.

But the motion and direction of the particles of water in a reservoir, before and at the time of entering an aperture, in one of its sides, occasions a *material* difference between the actual discharge and that computed from the theory of falling bodies. The friction, also, where the surfaces of the sides of the aperture is great, compared with its area, adds considerably to this difference.

It has been ascertained by a variety of accurate experiments, that the volume which flows through an aperture, placed in a vertical side of any vessel or reservoir, filled with water, has its diameter contracted at a short distance from the orifice, through which it issued; and that the area of its section, taken at right angles with its jet at the point of greatest contraction, is much less than the area of the aperture through which it issued.

The difference between these two areas and the consequent difference in the quantity of water, which actually flows, and the quantity which would flow, if unimpeded by the cause before mentioned, varies, under different circumstances, from near 200 to 358 parts in a thousand.

This variation is found to be much less affected by the ratio between the perimeter and area of the aperture; or by the distance at which it is placed below the surface of the water in the reservoir, than by its position as it respects the sides and bottom of the reservoir, and by other arrangements, which may serve to conduct the water, and secure to it a less interrupted horizontal movement in the direction of, and passage through, the aperture.

Thus, an orifice, placed in the side of a reservoir, actually discharged 920, and in one instance, 983 parts, when furnished with a conical or rather trumpet-shaped conductor, and only about 665 parts, without it: by which it appears, that the whole amount of obstruction, from friction and resistance of the air, did not exceed, and indeed could not equal the difference, or 80 and 17 parts in one thousand.

The difference in the proportions discharged in those cases where no conductor was employed, is chiefly attributed to the nature of the surfaces of the apertures; and to the greater or less ratio between the area of the aperture and the area of its surfaces. In no two such instances, however, (within those limits which concern the present inquiry,) did this difference exceed 23 parts in 1000.

It appears, then, that the computed body of water, at the National Armory, at Springfield, must exceed the actual amount employed by

a quantity, not greater than 335, nor less than 200 parts, in 1000. To determine this excess with accuracy, for each wheel, would require the aid of data, not in our possession; and to neglect it altogether, might occasion considerable errors in the estimate of the excavations and descent.

If we assume, however, the ratio between the actual and the estimated discharge, which may be found to hold, in relation to the aperture of the largest dimensions employed at Springfield, and apply that ratio to the reduction of the whole amount, deduced for all the apertures, we shall obtain a result somewhat greater than the actual quantity of water employed at that establishment; and yet approximate as near to it as may be done with prudence and safety.

Supposing the estimated discharge from the largest aperture is to the actual discharge, as 1000 : 800 : : (which corresponds very nearly with the experiments)

We have 1000 : 800 : : 335 : 268 for the whole quantity of water: and 1290 for the power of that quantity.

STATEMENT A.

Estimate of the Annual Quantity and Cost of Materials required for the Manufacture of 12,000 *Muskets.*

AT PITTSBURG.

100	tons refined iron, at 130 dollars	-	$13,000 00
26,880	pounds steel, assorted, at 14 cents	-	3,763 20
4,480	do brass and zinc, at 15 cents	-	672 00
2,240	do emery, assorted, at 12½ cents	-	280 00
60	do borax, at 60 cents	-	36 00
80	tons grindstones, at 20 dollars	-	1,600 00
20	do sand, at one dollar	-	20 00
20	do fire clay, at one dollar	-	20 00
12,000	rough gun stocks, at 18 cents	-	2,160 00
12,000	files, assorted, = 1,000 doz. av. at 3½ dollars	-	3,500 00
40,500	bushels pit coal, at three cents	-	1,215 00
10,000	do charcoal, at five cents	-	500 00
500	gallons spermaceti oil, at 75 cents	-	375 00
100	do linseed oil, at 62½ cents	-	62 50
4	barrels tar, at four dollars	-	16 00
400	pounds buff leather, at 33 cents	-	132 00
600	do band leather, at 30 cents	-	180 00
500	do glue, at 30 cents	-	150 00
2,000	do woollen rags, at two cents	-	40 00
2,000	bushels old shoes, at 12½ cents	-	250 00

30 reams sand paper, at five dollars - -	150 00
20 do wrapping paper, at two dollars - -	40 00
50 coal boxes and baskets - - -	50 00
Tallow and candles, 560 lbs. at 12½ cents - -	70 00
Transportation from Philadelphia, of 47,600 pounds, at three cents. See Statement D, - - -	1,428 00
	29,709 70
Browning materials, &c. estimated as at Springfield, 12,000 muskets, at 12 cents - - - -	1,440 00
Total	$ 31,149 70

AT BEAVER.

Materials, as at Pittsburg, excluding fuel - -	29,434 70
Add 40,500 bushels pit coal, at five cents - -	2,025 00
10,000 do charcoal, at four cents - -	400 00
Transportation of 122½ tons from Pittsburgh, at 150 cts. per ton - - - - - -	183 75
Total	$ 32,043 45

AT ZANESVILLE.

Materials, as at Pittsburg, excluding fuel - -	29,434 70
Add 40,500 bushels pit coal, at five cents - -	2,025 00
10,000 do charcoal, at three cents - -	300 00
Transportation of 122½ tons from Pittsburgh, (Statement D,) at 50 cents per 100 pounds - - -	1,372 00
Total	$ 33,131 70

NORTH BEND.

Materials, as at Pittsburg, excluding fuel - -	$29,434 70
Add 40,500 bushels pit coal, at 8 cents - - -	3,240 00
10,000 bushels charcoal, at 5 cents - - -	500 00
Transportation of 122½ tons from Pittsburgh, (statement D) at 45 cents per 100 - - - -	1,234 80
Total -	34,409 50

FALLS OF OHIO.

Materials, as at Pittsburg, excluding fuel - -	29,434 70
Add 40,500 bushels pit coal, at 10 cents - - -	4,050 00
10,000 bushels charcoal, at 5 cents - - -	500 00

Transportation of 122½ tons from Pittsburg, (statement D) at 50 cents per 100 pounds - - -		1,372 00
Total -		35,356 70

NARROWS OF HARPETH.

Materials, as at Pittsburg, excluding fuel - - -		29,434 70
Add 172,000 bushels charcoal, at 3 cents - -		5,160 00
Transportation of 122½ tons from Pitsburg to Nashville, (statement D) at $1 per 100 pounds, - - - - - -	$2744 00	
Transportation of same from Nashville to the Works on the Harpeth, 122½ tons, at $1 50 per ton - - - - -	183 75	
		2927 75
Total -		$37,522 45

CYPRESS CREEK.

Materials, as at Pittsburg, excluding fuel - - -		29,434 70
Add 172,000 bushels, at 3½ cents - - - -		6020 00
Transportation of 122½ tons from Pittsburg to Florence, (statement D) at $1 per 100 pounds -		2,744 00
Total -		38,198 70

STATEMENT B.

Pay roll of officers, mechanics, and laborers, according to the rates established at Springfield, Mass.

At Pittsburg, Penn.

Exclusive of attendance, &c. on the Steam Engines.

Superintendent - - - - -	$1,492 00	
Master Armorer - - - - - -	746 00	
Three Clerks, at 510 dollars each -	1530 00	
Paymaster and Storekeeper - - -	862 00	
Paymaster's Clerk - - - -	504 00	
Five Inspectors, or Assistant Master Armorer, at 576 dollars each - -	2,880 00	
Total Officers,		8,014 00
Labor, estimated as at Springfield, on 12,000 muskets, paid by the piece for each component part of the musket, at five dollars and twelve cents - -		61,440 00

Two forgemen, 208 days each, 416 days, at one dollar per day,	$ 416 90
Three helpers, 208 days each, 624 days, at 50 cents per day	312 00
Labor, estimated as at Springfield, on 12,000 wipers, 12,000 screw-drivers, 1,200 ball-screws, and 1200 spring vices	2,604 00
Jobbers and men hired by the day	11,300 00
Expense of three watchmen, one at one dollar, and two at seventy-five cents each	912 50
Total	$84,998 50

The jobbers are employed in making and repairing machinery and tools; in making all repairs to the works and buildings of the Armory; browning the muskets, performing all extra and incidental labor, and attending to the police of the establishment.

Pay roll of officers, mechanics, laborers, &c. at places where water power is employed.

Amount of pay roll as at Pittsburg,	84,998 50
Add for two millwrights	700 00
Total	$85,698 50

STATEMENT C.

Estimate of annual miscellaneous expenses at the different sites.

At Pittsburg.

Postage, stationery, and printing, at		$ 200 00
Forage, 12 tons hay, at 6 dolls. per ton	72 00	
200 bushels of corn, at 25 cents	50 00	
		122 00
Extra team work, (hired)		600 00
Materials for repairs of buildings, &c		600 00
Fuel for quarters, offices, and part of the workshops, 3,100 bushels pit coal, at three cents		93 00
600 gun boxes, at 130 cents		780 00
Total		$ 2,395 00

At Beaver.

Miscellaneous expenses, as at Pittsburg -	$2,395 00
Add to the cost of fuel at Pittsburg, two cents per bushel, for coal, 3,100 bushels, at two cents - -	62 00
For additional cost of gun boxes, at five cents each, 600 boxes, at five cents - - - - - -	30 00
Estimated annual expense of repairs to the water works, the gearing, &c. including materials; on the average duration of the wheels - - - -	700 00
Total	$3,187 00

At Zanesville.

Miscellaneous expenses, as at Pittsburg - -	2,395 00
Add to the cost of fuel at Pittsburg, two cts. per bushel, for 3,100 bushels, at two cents - - -	62 00
Additional cost of 600 gun boxes, at 20 cents - -	120 00
Estimated annual expense of repairs to the water works, the gearing, &c. including materials; on the average duration of the wheels - - - - -	700 00
Total	$3,277 00

At North Bend.

Miscellaneous expenses, as at Pittsburg - -	2,395 00
Add the difference between 93 dollars, the cost of fuel at Pittsburg, and 260 dollars, the cost of 260 cords of fire wood - - - - - - -	167 00
And additional cost of 600 gun boxes, at 20 cents each -	120 00
Estimated annual expense of repairs to the water works, the gearing, &c. including materials; on the average duration of the wheels - - - -	700 00
Total	$3,382 00

At Falls of Ohio.

Miscellaneous expenses, as at North Bend - -	2,682 00
Additional cost of 600 gun boxes, at five cents - -	30 00
Estimated annual expense of repairs to the water works, the gearing, &c. including materials; on the average duration of the wheels - - - -	700 00
Total	$3,412 00

AT THE NARROWS OF HARPETH, AND AT CYPRESS CREEK.

Miscellaneous expenses, as at Falls of Ohio - -	2,712 00
Additional expense of 600 gun boxes, at 20 cents -	120 00
Estimated annual expense of repairs to the water works, the gearing, &c. including materials; on the average duration of the wheels - - - -	700 00
Total	$3,532 00

STATEMENT D.

Weight of articles required annually at an armory, that are stated in the estimate of materials, at the average price on the sea-board, and which must be transported across the mountains to Pittsburg.

Steel - -	12	Tons
Brass and zinc -	2	do
Emery - -	1	do
Files, 1,000 doz. -	3	do
Spermaceti oil -	2	do
Buff and band leather	0½	do
Glue - -	0¼	do
Sand Paper - -	0½	do
Total	21¼	do

Equal 47,600 lbs. at 3 cents $1,428

Weight of articles to be transported from Pittsburg to all places below.

Articles brought from Philadelphia to Pittsburg, as above	21¼ Tons
100 Tons of iron - - - - -	100
For wrapping paper and stationery - - -	1¼
Total	122½

STATEMENT E.

Estimated cost of a steam power, for operating all the machinery required in the manufacture of 12,000 *muskets, annually, at Pittsburg, engines capable of working with* 100 *lbs. to the inch.*

One steam engine, with boiler complete, 15 inch cylinder, of 45 horse power, when working with a pressure of 30 lbs. to the inch,		$3,000 00
The fly wheel and main shaft, estimated at 6 tons weight, with brass boxes for journals,		666 00
Timber and lever beam,		75 00
Thirty M. bricks and laying, at $7¼,		217 50
One hundred and forty perches masonry laid, at $2,		280 00
		$4,238 50
One steam engine, with boilers complete, 13 inch cylinder, of 33 horse power, when working with a pressure of 30 lbs. to the inch, including masonry and furnace, and all other fixtures and appurtenances,		3,454 50
Two steam engines, with boilers complete, 11 inch cylinder, of 27 horse power, when working with a pressure of 30 lbs. to the inch, including masonry and furnaces, and all other fixtures and appurtenances, each $3,127 50,		6,255 00
Four wells, digging and walling, average 50 feet each, at $96,		384 00
Four pumps for wells, at $40,		160 00
		$14,492 00
Add, for contingencies, 10 per cent.		1,449 20
Total first cost, to put the steam power in operation,		$15,941 20
To which may be added, capital required to renew the wearing parts of engines, and render the power permanent, not included in the estimate of annual expenses,		5,811 00
		$21,752 20

STATEMENT F.

Estimate of the annual expenses of four steam engines for an armory at Pittsburg.

Working 313 days, at 160 bushels per day, is 50,080 bushels, at 3 cents per bushel,	$1,502 40
Oil, tallow, smiths' work in repairs, 313 days, at 40 cents per day for each engine, is 160 cents per day,	500 80
Packing pistons 4 times per annum, for each engine, is 16 times, at 175 cents,	28 00
Hire of 4 engineers, at $400 each, per annum,	1,600 00
	$3,631 20

Estimate of the quantity and cost of materials for the Dam at Beaver.

2,084.51 perches of hammered stone, of large size, dressed to dimensions, at $4 50 per perch, laid	$9,380 29
250 perches, at $2 per perch, at the wings	500 00
Cutting the stones, (grooves,) 1,600 running feet, at 75 cents per foot	1,200 00
266 bolts, 8 lbs. each, at 8 cents per lb.	170 00
Drilling 266 holes in cap stones, at 12½ cents each	33 00
1,600 feet ranging timber, at $5,	80 00
5,300 feet plank, 3 inches thick, at $9 per M.	133 10
Excavations and levelling foundation, (rock) 530 cubic yards, at 50 cents	265 00
Excavation for the wings, 100 cubic yards, at 50 cents	50 00
Gravelling and filling 1000 cubic yards, at 20 cents	200 00
Water cement and contingencies, and guard dam	1,020 00
Dollars,	13,631 39

The price of $2 per perch, for the masonry at the wings of the dam, includes the expense of clearing the foundations of those walls.

It is believed that limestone, capable of making good water cement, may be obtained at several places on the Ohio; near Wheeling, Virginia, for instance.

[*Here follow the Scale of Mr. Berthoud, of Shippingport, and that copied from Mr. Todd's papers, supposed to have been constructed by Mr. Brooks, exhibiting the rise of water at the Falls of Ohio, from ordinary low water, up to ten feet at Louisville.*]

A brief explanation of the Fixtures, (so termed) in the tables marked No. 2.

Cast Iron.—For gudgeons and sockets, for water wheels, for spur and pinion wheels, rings, slides, husks, &c. and beds for trip hammers, forge, &c.

Wrought Iron—For bolts, nuts, and screws; straps and braces for water wheels; bolts to secure the sills; and braces and straps to secure the harness for trip hammers; bolts to secure the grinding, polishing, and drilling frames; for arbors, or shafts, for grindstones, drums, and pinion wheels; and cams or tappets for forge and trip hammers.

Steel—For facing the cams, or tappets, &c. &c.

Oak Timber—For sills, posts, and harness for forge and trip hammers; sills and frames, for grindstones; polishing frames; drilling frames; head and centre blocks, and shafts for water wheels; and plank for work benches.

Pine Boards and Plank—For lining, buckets, &c. for wheels, and for making drums, and apartments, drawers, &c. for keeping the parts of work, and tools of the workmen.

Carpenter and millwright work.—For making the water wheels, head and centre blocks, and drums; for framing the sills and harness for the hammers; frames for grindstones, polishing, and drilling; and making the drawers, apartments, &c.

Stone, Brick, and Lime.—For forges, or fires, for trip hammers, forge, or other forges; for chimneys to the above forges and furnaces, for annealing and hardening work, and casting brass.

Fire-brick, and clay—For lining the inside of the furnaces.

Masons' labor—For laying the stone and brick.

From the fixtures at Pittsburg, the expenses of water wheels, gates, and head blocks, are deducted, and the calculations are made to operate the armory by steam power at that site.

MACHINERY AND TOOLS.

Number of machines.	No. sets of tools.	PURPOSE.	
14	14	For trip hammers and forge -	$1,342 67
7	7	For boring barrels - - -	530 00
20	34	For drilling, milling, slitting, turning &c. - - - -	2,308 00
	10	For forging locks - - -	845 00
	8	For forging mounting - - -	711 55
	3	For forging bayonets - - -	225 00
	1	For forging ramrods - - -	20 00
	40	For filing locks - - - -	1,213 00
	12	For filing mounting - - -	877 60
	5	For proving, breeching, filing, and sighting barrels - - -	177 50
6	34	For stocking muskets - - -	1,632 16
3	5	For making and repairing machinery, and tools - - -	1,877 66
	14	For finishing muskets - - -	219 36
9	9	For grinding - - - -	450 00
1	1	For boring bayonets - - -	50 00
	60	Anvils, not included in the above	1,012 50
	153	Vices do do do	780 00
		Carpenters' and millwrights' tools, patterns, &c. - - -	250 00
		Miscellaneous articles - -	1,549 00
			$16,071 00

The miscellaneous articles consist of one fire engine; 200 fire buckets; engine hose; twenty-four common buckets; six long ladders; two large scales, for weighing iron and steel; one scale for weighing loads of grindstone, &c; six writing desks for offices; twelve chairs for offices; twenty-five account books, ink stands, tables, &c. for offices; six wheel-barrows; one wagon; one set of harness, and two horses.

The machinery and tools, the latter amounting to more than ten thousand in number, are not given in detail, it being deemed unnecessary, though the estimate and cost was made on each machine, and tool, separately, at the Springfield prices; to which has been added ten per cent. which it is believed will cover the whole expense.

At the following places, viz: the three sites at the Falls of the Ohio river, the sites at the narrows of Harpeth, at North Bend, at Licking river, (Bowman's creek,) and at Zanesville; it is proposed to

use reaction wheels: they have been adopted from a conviction, that every other kind of wheel, within our knowledge, would be liable to interruption from high water. From our limited knowledge of the power and principle of operation of these wheels, and the effect or amount of resistance, caused by the friction of the wheel and part of the shaft running under a considerable depth of water, (as must sometimes be the case at several of the sites, particularly at the Falls of the Ohio,) it was thought most safe to adopt fourteen wheels. Having obtained some further knowledge, from a more minute examination of the subject, as regards their power and capacity of operating under water, with an efficient head, we are satisfied, that seven reaction wheels will be sufficient for the operations of the Armory. The tables, therefore, marked No. 1, exhibit the quantity of excavation and masonry, and the cost, first for fourteen wheels with forge, and lastly for seven wheels. The estimates, however, are for seven wheels at the sites above named. In our first calculation, we omitted the Forge at the sites, having one in the immediate vicinity; but, from our estimate, it was found, that a Forge would add to the economy and convenience of the establishment. It is, therefore, now included in the estimates for all the sites. The following is an explanation of the forebays and races, and the operations to be performed by each wheel.

Forebay, No. 1, (marked 1 in the tables) conveys the water from the Canal to two wheels, No. 1 & 2; they are separated by a triangular wall or pier, and of course there are two races, No. 1 & 2, (marked 1 & 2 in the tables,) which unite near the river wall; and the water from both races, passes through the same arch or space in the wall, calculated for that purpose. Wheel, No. 1, is calculated to operate six trip-hammers, (and five bellows,) two for drawing iron and steel to the proper size for forging the component parts of the musket; one for welding and drawing scrap steel and old files; and one for drawing and rounding ramrods; and two for drawing and rolling scraps for barrels.

Wheel No. 2, is to operate eight light hammers and eight bellows, for welding barrels.

Forebay, No. 2, (marked 6 in the tables,) conveys the water to wheels, No. 3 & 4; the same as described in forebay, 1. The races are marked 10 & 11 in the tables. These wheels are calculated to operate nine large gridnstones, for grinding all parts of the musket requiring that operation.

Forebay, No. 3, (marked 7 in tables,) conveys the water to wheels, No. 5 & 6, (races, 5 & 6, marked 12 & 13 in tables,) calculated to operate machinery for boring, turning, and milling barrels; boring, turning, and milling bayonet sockets; for drilling, milling, slitting, turning, and polishing, all parts that require it; and the machinery for turning the stock, boring for the barrel, letting in the lock, and other operations in stocking the musket.

Forebay, No. 4, (marked 8 in tables, same as 5 in size; race 14, in tables, same as 9 in size,) is to conduct the water to wheel, No. 7; which is to operate the forge hammers, for working over the scrap iron and bad steel, and making such drafts as may be required for

machinery and tools. In cases where a variety of operations are to be performed by one wheel, it is calculated to have governors, (so called) to regulate the motion of the wheel; these machines are calculated to raise the gate and give additional power, by increasing the column of water on the wheel, when the motion is too slow, and depress the gate and diminish the column, when the motion of the wheel is too rapid; by this means a regular and nearly uniform motion is preserved in the operation of all the wheels and machinery.

At Cypress, four breast-wheels are calculated to be used, and one under-shot or reaction wheel.

Forebay No. 1, conveys the water to wheel No. 1, which is calculated to operate six trip-hammers and five bellows (as per note for reaction-wheels.)

Forebay 2, conveys the water to wheel No. 2, which is to operate eight light trip-hammers and eight bellows for barrel welding.

Forebay 3, conducts the water to wheel No. 3, which is to operate nine large grindstones.

Forebay 4, conducts the water to wheel No. 4, which is to operate machinery for boring, turning, drilling, milling, slitting, polishing, &c.

Forebay 5, is to conduct the water to the wheel which operates the forge-hammers' operations, as heretofore described.

The races are marked same as the forebays.

The site at the Falls of Big Beaver creek is calculated for two overshot, two breast, and one undershot or reaction wheels.

Forebay No. 1, is to convey the water to wheel No. 1, (breast) which is calculated to operate six trip-hammers and five bellows; two for drawing iron and steel to the proper size for forging the component parts of the muskes; one for welding and drawing scrap steel and old files; one for drawing and rounding ramrods; and two for drawing and rolling scalps for barrels.

Forebay No. 2, conveys the water to wheel No. 2, (breast) which is to operate eight light trip-hammers and eight bellows for welding barrels.

Forebay No. 3, conveys the water to wheel No. 3, (overshot,) to operate nine large grindstones for grinding all parts of the musket requiring that process.

Forebay No. 4, conveys the water to wheel No. 4, (overshot) which is to operate the machinery for boring, turning, and milling barrels and bayonet sockets; for drilling, milling, slitting, turning, and polishing, all the component parts that require it, and the machinery for stocking.

Forebay No. 5, is to convey the water to wheel No. 5, (undershot) to operate the forge-hammers for working over the scrap iron and making such drafts as may be necessary for machinery, tools, &c. The races are to conduct the water from the wheels of corresponding numbers.

At the Falls of Youghiogheny, (Ohiopile) it is calculated to use three breast and two overshot wheels,

Forebay No. 1, conducts the water to wheel No. 1, (breast.)

Forebay No. 2, conveys the water to wheel No. 2, (breast)—operations the same as at Beaver.

Forebay No. 3, at the end of race 1, conducts the water to wheel No. 3.

Forebay No. 4, at the end of race 2, conveys the water to wheel No.—4. operations same as at Beaver.

Forebay 5, leading from race 2, is to convey the water to the forge wheels. A basin receives the water from the canals, and forebays 1 and 2 conducts it from the bason to the wheels, as above stated; it is supposed when wheels 1 and 2, are in operation, the water will be sufficient to keep in motion the other wheels, which are placed on the next bench below; but to avoid any difficulty on that account, and to furnish water for the lower wheels, when the upper wheels stop, a race leading from the basin to each of the races 1 and 2, will, at all times, furnish an abundant supply. It is also believed that the water from the upper wheels may be carried over the lower wheels by means of a conductor, (to be raised and replaced at pleasure by means of a lever) when the lower wheels are stopped, and the upper ones in motion, but it may be necessary to have a space near the top of the forebays to serve as a wier to let off the surplus water, and races of moderate dimensions to conduct it into the races below the wheels; the expense for which was not included in the estimate—the amount however, will be small.

A LIST of the various operations in the Manufacture of a Musket, as now practised at the United States Armory, Springfield, Mass.

The Barrel.

Cutting scalps	by water,	Filing barrel	manual.
Drawing do.	do.	Studding do.	do.
Rolling do.	do.	Straightening do.	do.
Welding barrel	do.	Finish boring do.	by water,
Nut boring do.	do.	Drilling vents, do.	do.
Counter boring do.	do.	Polishing do.	do.
Smooth boring do.	do.	Browning do.	manual,
Turning do.	do.	Forging breech pin	do.
Milling do.	do.	Milling do.	by water,
Drawing do.	do.	Cutting screw do.	manual,
Breeching do.	manual,	Filing do.	do.
Proving do.	do.		

Bayonets.

Forging bayonets -	manual,	Grinding bayonet blades,	water,
Tempering do. -	do.	Do. Flutes -	do.
Boring do. socket -	by water,	Cutting & fitting socket,	manual,
Turning do. do. -	do.	Polishing bayonet -	by water,
Milling do. do. -	do.	Browning do. -	manual,

Ramrods.

Drawing ramrods,	by water,	Straitening ramrods	manual,
Rounding do. -	do.	Grinding do.	water,
Heading do. -	manual,	Polishing do.	do.
Tempering do. -	do.	Cutting screw - -	manual.

Bands.

Cutting upper band	water,	Filing upper band -	manual,
Welding do. - -	manual,	Grinding do. - -	water,
Drilling do. - -	water,	Polishing do. - -	do.
Sighting do. - -	manual,	Browning do. - -	manual.

Middle Bands.

Forging middle bands,	manual,	Riveting swivel to m. band,	man.
Trimming do. -	water,	Polishing do. - -	water,
Filing do. - -	manual,	Browning do. - -	manual.
Grinding do. - -	water,		

Lower Band.

Cutting lower band	water,	Grinding lower band	water,
Welding do. -	manual,	Polishing do. -	do.
Filing do. -	do.	Browning do. -	manual.

Swivels.

Forging swivels -	manual,	Turning swivels, -	water,
Trimming do. -	do.	Polishing do. - -	do.
Punching do. - -	do.	Browning do. - -	manual.
Filing do. - -	do.		

Guards.

Forging guard plates,	manual,	Milling guard bows,	water,
Trimming do. - -	water,	Filing do. - -	manual,
Filing do. - -	manual,	Rivetting guard bows,	do.
Drilling do. - -	water,	Grinding guard, -	water
Counter sinking do.	do.	Polishing do. - -	do.
Forging guard bows	manual,	Browning do. - -	manual.

Trigger.

Forging trigger, -	manual,	Polishing trigger -	water,
Trimming do. -	water,	Hardening do. -	manual.
Filing do. - -	manual,		

Side Plates.

Cutting side plates	water,	Grinding side plates	water,
Filing do. - -	manual,	Polishing do. - -	do.
Punching do. - -	water,	Browning do. - -	manual.

Band Springs.

Forging band springs	manual,	Polishing band springs	water,
Milling do. - -	water,	Browning do. - -	manual.
Filing do. - -	manual,		

Breech Plate.

Forging breech plate	manual,	Filing breech plate -	manual,
Trimming do. - -	water,	Grinding do. - -	water,
Punching do. - -	do.	Polishing do. - -	do.
Countersinking do. -	do.	Browning do. - -	manual.

Side Screws.

Forging side screws	manual,	Milling side screws -	water,
Turning heads, do. -	water,	Cutting screws -	manual,
Slitting do. - -	do.	Hardening do. - -	do.

Tang Pin.

Forging tang pin -	manual,	Cutting screw, do. -	manual,
Slitting do. - -	water,	Hardening do. -	do.
Milling do. - -	do.		

Breech Plate Screws.

Forg'g breech plate screws, man.		Cutting screw, do. -	manuel,
Slitting do. - -	water,	Hardening do. - -	do.
Milling do. - -	do.		

Guard Screws.

Forging guard screws	manual,	Cutting screws, do. -	manual,
Slitting do. -	water,	Hardening do. -	do.
Milling do. -	do.		

Lock Plate.

Forging lock plate -	manual,	Trimming lock plate	water,
Grinding do. - -	water,	Filing do. - -	manual.
Drilling do. - -	do.		

Hammer.

Forging hammer, -	manual,	Drilling hammer -	water,
Trimming do. - -	water,	Filing do. -	manual.

Brass Pans.

Castingpans - -	manual.	Filing pans - -	manual,
Boring do. - -	water,	Fitting do. - -	do.

Cock.

Forging cock - -	manual,	Punching cock -	water,
Trimming do. - -	water,	Filing do. - -	manual.
Drilling do. - -	do.		

Tumbler.

Forging tumbler -	manual,	Drilling tumbler -	water,
Milling do. -	water,	Filing do. -	manual.

Bridles.

Forging bridles -	manual,	Milling bridles -	water,
Drilling do. -	water,	Filing do. - -	manual.

Seers.

Forging seers - -	manual,	Filing do. - -	manual.
Drilling do. - -	water,		

Upper Jaws.

Forging upper jaws -	manual,	Drilling upper jaws -	water,
Trimming do. -	water,	Filing do. -	manual.

Cock Pin.

Forging cock pin -	manual,	Drilling cock pin -	water,
Milling do. -	water,	Cutting screw -	do.
Slitting do. -	do.		

Lock Pins.

Forging set lock pins	manual,	Cutting screw, lock pins	manual,
Slitting do. -	water,	Polishing lock -	water,
Milling do. -	do.	Hardening do. -	manual.

Main Spring.

Forging main spring	manual,	Tempering main spring	manual,
Drilling do. -	water,	Filing do. -	do.
Turning do. -	manual,		

Hammer Spring.

Forging hammer spring	manual,	Turn'g hammer spring	manual,
Drilling do. -	water,	Tempering do. -	do.
Filing do. -	manual,		

Seer Spring.

Forging seer spring	manual,	Turning seer spring	manual,
Drilling do. -	water,	Tempering do. -	do.
Filing do. -	manual,		

Stocking Musket.

Turning stock - -	water,	Finish stock'g musket	manual,
Boring for barrel -	do.	Finishing musket -	do.
Setting in the lock -	do.	Drawing iron -	water,
Fitting on the bands	do.	Drawing steel -	do.
Fitting to the heel plate	do.		

STATEMENT

OF THE

Dimensions, Excavations, and Masonry, for Canals,

AT

THE SEVERAL SITES.

REMARKS.

In calculating the descents of the canals, the velocity of the current is supposed to be uniform from the commencement, which is not exactly the case; some distance being passed over before the resistance of the sides and bottom is in equilibrium with the accelerating force, and whenever the descent is augmented, this difference is repeated. No correction is made for the effect of a change of direction; where the canal passes through earth, the velocity allowed, is so small, that the whole descent is generally too inconsiderable to affect either the excavations or the head of water on the wheels in any material degree, and indeed is less than the probable errors that occurred in taking the levels. In those cases, where the canal is taken through rocks, and a considerable velocity given to the current, its course varies but little from a straight line. The canal at Zanesville, makes the greatest angle in any case, where the velocity is greater than 12 inches per second; and there, the circumstance is of no consequence. It was necessary, however, to allow for other causes of difference, that would far exceed in their practical effect, those just enumerated. The increased perimeter of the canal, compared with its area, occasions obstructions to the current, of various kinds, and at the commencement of winter, by ice. It is frequently remarked of the western streams, that they are liable to be reduced nearly as low by frost as by drought. To meet all these contingencies, an allowance is made in calculating the descent, of half an inch per foot for the increase of the perimeter, and an addition of 12 inches to the depth, and 12 inches to the width of the canals, is made in estimating the excavations. The allowances, however, vary in different cases. They are greatest at those places that unite sufficient advantages to

bring them fairly into competition as sites for an armory; and at others, where the object was merely to show the least amount of excavation that would evidently be indispensable, they were omitted altogether.

The quantity of excavations required for a canal to convey a given quantity of water at a certain distance below the surface of the ground, may be diminished in a greater ratio than the cost per cubic yard will increase, by augmenting its depth, and contracting its width at bottom; until, in fact, the transverse section becomes a triangle. But it is evident that a canal so constructed, would be attended with serious inconvenience; and it is believed, that the width at bottom should not be less than the least depth of water which it is intended to contain.

The sections of the different canals, have been regulated, in this respect, by the same considerations which are stated above to have governed in making allowances for obstructions, &c. Thus, the excavations for the canals at Zanesville, Beaver, Ohiopile, Cypress, and North Bend, are considerably increased; for Zanesville, Beaver, and Ohiopile, in particular; and at Beaver, the velocity, where the canal passes through earth cutting, is reduced to 9 inches per second, instead of 12, as estimated elsewhere. At Bowman's creek, the least velocity is 12 inches per second; and 18 at the Falls of Ohio. No allowance is made, in either case, for obstructions to the current; these canals having the same dimensions as the columns of water in motion, with velocities due to their respective descents.

Site on Cypress Creek, near Florence, Alabama, at Clopper's, or Schlatter's Mill.

SITE No. 2.

The site at H B, below Clopper's mill, is two and a half miles from the Tennessee river; and the foot of the mill dam is 53 feet above the low water of that river, and 36 feet above its highest rise.

From the foot of the mill dam at A, to B, the whole fall is 14 feet eight inches.

The extreme rise of Cypress creek is stated at ten feet.

The surface of a dam, eight feet high at A, would, therefore, be twelve feet eight inches above the level of the highest rise of the creek, near the last water shop, at B.

From all the testimony that has been collected, it appears unnecessary to employ the difference of level between high and low water, at B, for the purpose of increasing the power of the site. Breast wheels may not only be employed without hazard of interruption, but will, most probably, be sufficient, without resorting to the use of reaction wheels, which would add considerably to the quantity and expense of the excavations.

The canal will pass through a clay soil, and the velocity of the current will not exceed twelve inches per second; the descent is, therefore, inconsiderable—eighteen inches will then be sufficient to free the wheels from tail water, to include both the descent of the canal, and the small difference of level that will exist between the surface of high water in the creek, opposite the first and last water shops, and eleven feet, head and fall, may be employed on the wheels.

The forge will be included in the estimate for this site; the power required, is 1032; and the quantity of water, for four breast wheels, 138 cubic feet per second, nearly.

From the dam at A, to the proposed position for the water shops, the surface of the ground is an inclined plane, descending with great regularity towards the river; and leaving it optional to take the canal along the whole route, at any required depth below the surface.

It will be proper, however, to take the canal from a point above the dam, where the ground is higher than the greatest elevation of the creek, which cannot exceed eight feet. If the extreme rise below the dam is only ten feet, the average depth of cutting above the level of low water in the canal, will, therefore, be assumed at ten feet for the first 150 yards, which will be amply sufficient to include all the excavation that may be necessary in taking the canal round the dam to where the ground has any given elevation; and, from thence, to the last water shop, the depth of cutting may be assumed at pleasure, and without risk.

Excavations of Canal Earth.

PLAN C.

1. From A, at the head of the proposed canal, to D, where the ground is at command, the distance is assumed, and it is believed without hazard, at 450 feet.

The width of the canal, at bottom, will be taken equal to the depth of water contained in it.

Then $\sqrt{\frac{138\times 2}{5}} = \sqrt{55.2} = 7.43$ feet; the least depth of water.

$7.43 + .67 = 8$ feet depth of canal below the surface of the water, including $\frac{67}{100}$ of a foot for obstructions, which is also the width at bottom.

1. Average depth of ground above the level of the dam = 10 feet.
2. Depth of canal below the level of the dam = 8

Mean depth of earth to be excavated = 18 feet.

$\frac{18\times 3}{2} + 8 = 35$ feet, mean width of canal.

$35 \times 18 \times 450 = 283{,}500$ cubic feet.

94,500

10,500 cubic yards, averaging 18 feet deep.

2. From D, to the first water shop at H, $= 4422 - \overline{450 + 620} = 3352$ feet.

1. Average depth of ground above the level of the dam = 1.0 feet.
2. Depth of canal below the level of the dam = 8.

Mean depth of earth to be excavated = 9.0 feet.

$\frac{9\times 3}{2} + 9 = 22.5$ feet, mean width of canal.

$9 \times 22.5 \times 3352 = 678780$ cubic feet.

226260

25140 cubic yards, averaging nine feet deep.

3. From H, to the last water shop at B = 620 feet; the surface of the water in the canal will be two feet below the surface of the ground, when,

1. Average depth of ground above the level of the dam =2.
2. Depth of canal below the level of the dam =8.

Mean depth of earth to be excavated =10. feet.

The side of the canal next the water shops will be walled. Then

$\frac{10}{4}$ =2.5 feet, mean thickness of side wall.

$2.5+\frac{2.5}{4}=3.125$ feet, or 3.2 nearly; thickness of wall at its base.

3.2+1.2=4.4 feet. width of foundation.

2.75 feet, depth of foundation.

$8-\frac{1.2}{2}=7.4$ feet, width of bottom of canal between the inner edge of the foundation, and base of the opposite bank.

$\frac{10\times3}{4}+7.4=14.9$ feet, mean width of the solid to be excavated, comprised between a line perpendicular to the inner edge of the foundation of the side wall, and opposite bank of the canal.

14.9×10=149 square feet; area of its transverse section.

10+2.75=12.75 feet; depth from surface of ground to bottom of foundation.

$\frac{12.75}{2}+4.4=10.775$ feet; mean width of the solid to be excavated, including the space to be occupied by the side wall, and its foundation.

10.775×12.75=137.38 square feet; area of its section.

149+137.38=286.38 square feet; area of the transverse section of the whole solid.

620+10.775=630.77 feet; whole length of the solid to be computed.

286.38×630.77=180639.9 cubic feet.

60213.3

6690.3 cubic yards, averaging eleven feet deep.

Recapitulation of Earth to be excavated.

1. From A to D=10,500 cubic yards, averaging 18 feet deep.
2. From D to H=25,140 cubic yards, averaging 9 feet deep.
3. From H to B= 6,690 cubic yards, averaging 11 feet deep.

Total 42,330 cubic yards.

Masonry of Canal.

1. From H to B= 620 feet length of side wall. To which must be added the width of the canal at the surface of the ground, and the breadth of the foundation of the fall, which will include the end wall: nearly,

$\frac{10\times 3}{2}+10+4.4+\frac{10}{8}=30.65$ feet; length of end wall.

$620+30.65=650.65$ feet; whole length of wall to be computed.

$2.5\times 10=25$ square feet; area of the transverse section of wall above the foundation.

$2.75\times 4.4=12.1$ feet; area of the section of the foundation.

$25+12.1=37.1$ square feet; area of the transverse section of the whole wall and foundation.

$37.1\times 650.65=24139.1$ cubic feet.

Or, 975.3 perches.

Site at the Narrows of Harpeth River, Tennessee.

It is proposed to convey the water from the outlet of the tunnel at B. (plan H.) to the mouth of the ravine at G, by means of a side, or river wall, along the base of the hill. Assuming the highest rise of the Harpeth, to be 25 feet above low water, between the tunnel and ravine; and that four feet head may be employed on the wheels at that time, it will follow that the wall must be built near 31 feet high, to be secure.

The water will be taken into the ravine at G.; from thence, to the head of the canal at T, the bottom of the ravine is supposed to be sufficiently low, to render any excavation unnecessary, except for the foundation of the side wall.

The mean elevation of the Harpeth, during the winter and spring, is stated to be three feet; the whole fall at the water shops, is 18 feet (nearly) at low water: reaction wheels may operate therefore, with a head of thirteen feet without inconvenience: and as the supply of water is presumed to be sufficient with that head, a dam may be dispensed with, unless the whole fall should prove to be less than four feet during a high state of the river. But the opposite evil is most to be apprehended, and may have to be provided against. It will be adverted to at the close of this estimate.

Excavation of the Canal.

Plan H. Profile on line T. E.

13 feet head on the wheels. Forge and saw mill omitted.
150 cubic feet of water required per second: the velocity and descent are trifling; and not considered.

From T, at the head of the canal, to the last water shop at E, is 640 feet. To this distance, must be added the mean width of the transverse section of the solid, which includes the space to be occupied by the end wall, and its foundation.

The average elevation of the ground, from T to E, is 44 feet, (nearly) above low water, at corresponding points of the river: therefore $44-18=26$ feet, is the average height of the ground above low water, in the canal. Also, $\overline{25+4}-18=11$ feet, is the difference of level between high and low water in the canal, and determines the height of the side wall, which should be a foot higher, or 12 feet above low water in the canal, supposing always only four feet water in the wheels, when the river is swollen to its greatest (assumed) elevation below the tunnel. Allowing six feet for the least depth of water in the canal, the whole height of the side wall, above its foundation, is then, $12+6=18$ feet, and $26+6=32$ feet, for the average depth of the excavation, from the surface of the ground to the bottom of the canal.

$\frac{150}{6}=25$ feet; the mean width of the column of water.

$25-\frac{3\times 6}{4}-\frac{6}{16}=21.875$ feet; mean width of canal at bottom.

$21.875-.75=21.125$ feet, width from the inner side of the foundation to the base of the opposite bank of canal.

$\frac{32\times 3}{2}+21.125=69.125$ feet, width of canal at surface from the ground, exclusive of the base to the talus of the wall; and of the foundation which projects beyond it.

$\frac{69.125+21.125}{2}=45.125$ feet; the mean width.

$45.125\times 32=1444$ square feet; area of transverse section.

Again: $\frac{18}{4}=4.5$ feet; mean thickness of the side wall.

$4.5+\frac{18}{16}=5.625$ feet, or 5.6 nearly: thickness at its base.

$5.6+1.5=7.1$ feet, or 7 feet nearly; thickness of the foundation, and 3 feet the depth of the foundation.

$\frac{32+3}{4}+7=15.75$ feet, mean width of that portion of the transverse section of the whole solid, which embraces the side-wall and its foundation.

$15.75 \times 35=551.21$ square feet, its area: and

$1444+551.21=1995.25$ square feet, the area of the transverse section of the whole solid to be excavated.

$640+15.75=655.75$ feet, length of the solid.

$655.75 \times 1995.25=1308385.18$ cubic feet, or 48458.71 cubic yards of earth, averaging about 33 feet deep.

2d. Excavations for the foundation of the side wall, from G to T. The average height of this wall, will be 22 feet, nearly, above its foundation.

$\frac{22}{4}=5.5$ feet; mean thickness of the wall,

$5.5+\frac{22}{16}=6.875$ feet, thickness at its base.

$6.875+1.5=8.375$ feet, thickness of the foundation.

3 feet, mean depth of foundation.

$8.375 \times 3=25.125$ feet, area of its section (nearly.)

$25.125 \times 76=1909.5$ cubic feet,

70.5 cubic yards, averaging 3 feet deep.

The height of the ground has been stated at 44 feet, and the height of the canal wall at 18 feet; the watershops will be about 30 feet above low water; there is consequently, a body of earth between the canal and the river, which it will be necessary to remove; extending the whole distance from T to E. The area of that portion of its transverse section which has not been included in calculating the excavations of the canal and river wall *of the shops*, is about 780 square feet: the whole solid is, therefore, $780 \times 615=$

479700 cubic feet, or

17766·6 cubic yards, averaging near 12 feet deep,

MASONRY.

1 canal wall from T to E. = 640 feet,
2 end wall at E = 43 feet (nearly,)

Making, 683 feet;

from which must be deducted for four forebays, viz:

3 forebays of 12 feet width, each = 36 feet.
1 forebay of 8 feet width, 8 feet.

44 feet.

$683-44=639$ feet, actual length of canal wall to be computed.

$4.5 \times 18=81$ square feet, area of the transverse section of the wall above its foundation.

$7 \times 3 = 21$ square feet, are of the section of foundation.
$81 \times 21 = 102$ square feet; area of transverse section of the whole wall.
$102 \times 639 = 65178$ cubic feet, or
2633.45 perches.

The length of side wall in the ravine, from G to T, is 76 feet (nearly,) viz: 106—30.

$5.5 \times 22 = 121$ square feet, area of its section above the foundation.
$8.375 \times 3 = 25.125$ square feet, section of the foundation.
$121 + 25.125 = 146.125$ square feet, area of the transverse section of thewhole wall.
And $146.125 \times 76 = 11105.5$ cubic feet, or
448.7 perches.

River wall from the outlet of the tunnel, to the mouth of the ravine at G, including the turn of the wall at each end, is 2142 feet. It will necessarily vary in its dimensions, as it changes its relative position, in respect to the direction of the current acting against it. Its average heighth, will be 31 feet above its foundation, and the area of its probable mean transverse section, including the foundation, may be taken at 350 square feet, without much error.

$350 \times 2142 = 749.700$ cubic feet, or
30,290.9 perches.

Some excavation will be required for the wall, but, as advantage will be taken of the bayou, from the outlet of the tunnel, to where it empties into the river at O, the quantity must be trifling, except for the foundation, which will have an area of 45 square feet, for its probable mean transverse section.

Consequently,

$45 \times 2142.0 = 96390$ cubic feet, or

3570 cubic yards,

of earth to be removed.

RECAPITULATION.

1. *Excavation of earth.*	*cubic yards.*
1. for foundation of the river wall, from the tunnel to G,	3570
2. For foundation of side wall from G to T, averaging 3 feet deep,	70
3. For the canal from T to E, averaging 33 feet deep,	48458.71
4. Earth to be removed from the surface between the canal and river, averaging 12 feet deep,	17766.6
2. *Masonry.*	*perches.*
1. Canal wall, from T to E,	2633.45
2. Side wall, from G to T,	448.7
3. River wall, from the tunnel to G, faced with hammered stone,	30,290.9

Site below Shippingport Falls of Ohio.

(Plans S and L, No. 1.) (Profile No. 1.)

1. Dimensions of the transverse section of the column of water in the canal, from *b* to *K*, (Plan *S*. Prof. No 1,) when even with or barely over the average surface of the Rock, in that distance: and the velocity 1½ foot per second.

The average height of the Rock above low water level, is = 2.73 feet. When the rise of the Ohio is 3 feet above the Falls, the rise below is 12 feet: the water in the canal will then be even with the surface of the rock; and the whole difference of level at that time is 24+3—12=15 feet. (See Table.)

The descent of the surface of the water in the canal will then be near 6 inches; the head on the wheels, 14½ feet; and the quantity of water required for the works, 142.34 cubic feet, or 143 nearly.

	Feet.
Descent from *A* to *b*, at low water, (bottom of canal) -	= 0.5
Descent from *b* to *K*, at low water = 1 foot, half the difference between the descent of bottom of canal and surface of water, at the time of 3 feet rise above the Falls = $\frac{1-\cdot 5}{2.}$	= 0.25
Least depth of water in canal, at lowest stage - - - -	4.0
Average height of rock above low water level - - - -	2.73
Mean depth of the column of water - - - - - -	7.48

$\frac{143}{1.5}$ = 95.33 square feet for the area of the mean transverse section.

and $\frac{95.33}{7.48}$ = 12.74 feet, nearly, for the breadth: the sides being perpendicular.

2. Dimensions of the transverse section of the column of water, from *b* to *K*, above the surface of the rock, when the head on the wheels is 4 feet or less:—And velocity, 18 inches per second. When the rise above the Falls is 9 feet, the rise below is 28½ feet. The whole difference of level is then 24+9—28½=4½ feet.

The descent of the surface of the water in the canal will be 6 inches nearly; the head on the wheels 4 feet nearly; and the quantity of water required = 516 cubic feet per second.

$\frac{516}{1.5}$ = 344 the area of the section from the surface of the water to bottom of canal.

But the area of this section includes that of the section through the rock just before determined: consequently, 344—95=33=248=67

square feet is the area of that portion of the section above the surface of the rock.

To the difference between the height of the rise in the river when the water in the canal is even with the average surface of the rock, and the height of the rise, when the head on the wheels is only 4 feet, should be added half the difference of the descent from *b* to *K*, at each period. Neglecting this difference, and taking half the descent in the former case, the altitude becomes $9-3+\frac{5}{2}=6.5$ feet, which is greater than the truth; and will therefore require a less excavation. Hence, the mean breadth of this portion of the section is $\frac{248.67}{6.5}$ $=38.25$ nearly. Again: the base of the slope to the sides of the canal above the rock, is one and a half times its altitude to the surface of the water; from thence to the surface of the ground, the base is equal to the altitude: therefore, $38.25-\frac{3\times6.5}{2}=28.5$ feet; the breadth at bottom, or surface of the rock: and $38.25+\frac{3\times6.5}{2}=48$ feet; the breadth at the surface of the water.

The mean depth of earth from the surface of the ground to the rock, is 16.72 feet.

$16.72-6.5=10.22$ feet, the distance from the surface of the water to that of the ground: and,

$48+10.22\times2=68.44$ feet is the width of the excavation at the surface of the ground.

And then, according to the hypothesis, are the dimensions of the mean transverse section of the canal between *b* and *K*, requisite to convey the necessary quantity of water to the works at the two stages of the river, which limits the size of the canal at all others.

3. Dimensions of the transverse section of the canal from *K* to its end at *L*, when the head on the wheels is 4 feet or less, and the velocity of the current 18 inches per second.

	Feet.
1. Descent in bottom of canal from *A* to *b* - - - - -	0.5
2. Descent from *b* to *K* - - - - - - - - -	1.0
3. Least depth of water in the canal during a low stage of the river - - - - - - - - - - -	=4.0
Making the whole depth of the bottom of the canal at *K* below the level of low water - - - - - - -	=5.5

Nothing is allowed for the descent of the bottom from *K* to *L*, because the canal will preserve a uniform width to the last water shop; and the trifling descent necessary, in this distance, will occur in the

diminished depth of water at the lower end, where the consumption of it ceases.

The whole depth of the bottom of the canal at *K*, below the level of low water mark, added to the elevation of the water above it, when the rise of the Ohio is 9 feet above the falls, will be the depth of the column of water between *K* and *L*, nearly, when the head on the wheels is 4 feet or less, viz:

	Feet.
1 - - - - - depth of bottom at *K* below low water -	5.5
2. Rise in the Ohio above the falls, when the head on the wheel is 4 feet - - - - - - - - - - -	9
	14.5
From which should be deducted the descent at the surface at that time, or near 6 inches from *b* to *K* - - - -	0.5
Leaving the actual depth of the column of water - - =	14.0

The quantity of water required to a head of 4 feet is 516 cubic feet per second; the velocity of the current is taken at 18 inches per second; therefore,

$\frac{516}{1.5} = 344$ square feet, for the area of the section.

From *K* to *L* there is no rock; the side next the river will be walled: the base of the slope to the side which is of earth, is one and a half times its altitude to the surface of the water: from thence to the surface of the ground the base is equal to the altitude.

The base of the talus to the wall is $\frac{1}{8}$ of its altitude:

$\frac{516}{1.5} = 344$ feet; the area of the section, of which the depth is 14 feet, as before determined.

$\frac{344}{14} = 24.57$ = the mean breadth of the section.

$24.57 - \frac{3\times14}{4} - \frac{14}{16} = 13.195$ feet, the breadth at bottom of canal; and $24.57 + \frac{3\times14}{4} + \frac{14}{16} = 35.945$ feet; the breadth, at surface of the water.

The average height of the ground above the level of low water, from *K* to *L*, is = 20.66 feet.

The depth or distance below the level of low water to the bottom of the canal is = 5.5 feet.

20.66 + 55 — 14 = 12.16 feet height from the surface of the water in the canal to the surface of the ground, when the rise of the Ohio is 9 feet above the falls.

$35.945 + 12.16 + \frac{12.16}{8} = 43.4375$ feet: the breadth of the canal

at the surface of the ground; the side next the river being of masonry, and the opposite side of earth.

The dimensions of the transverse section of the canal at low water, from *A* to *b*, as well as the position of the wheels, depend on the quantity of water which can be conveyed along the portion of the canal, from *K* to *L*, at that stage of the river.

When the river is at its lowest stage, the depth of water in the Canal, from K to L, is four feet, nearly.

The breadth of bottom, as just before determined, is 13.195 feet. $13.195+\frac{3\times4}{4}+\frac{4}{16}=16.445$ feet, the mean breadth of the transverse section. $16.445\times4=65.780$ square feet, the area of the section. The velocity of the current cannot exceed 1½ foot per second, as before. $65.78\times15=98.67$ cubic feet per second, which requires twenty-one feet head on the wheels. The least depth of water in the Canal, from A to b, is four feet; the descent assigned to that distance, is six inches, and the corresponding velocity to that descent, with a breadth of eleven feet, is 27.3 inches per second, nearly, which gives 99.88 cubic feet. The velocity in the Canal from b to K, at low water, with the assigned descent to that distance, and uniform depth of four feet, is but little more than twenty-two inches, which gives 93.73 cubic feet, nearly.—Consequently, the surface of the water will be depressed at K, and the velocity increased to two feet, nearly; or, $\frac{1}{10}$ of a foot, nearly, be added to the descent of the bottom of the Canal, beyond what has been assigned.

These dimensions are obviously less than what would admit a practical application. No allowance is made, as in all other cases, for an extension of the perimeter, from irregularities, &c. nor any thing for accidental or other interruptions to the current, such as ice, &c. And a greater velocity is allowed to the current from K to L, with four feet head on the wheels, than would be admissible in practice.

It is assumed, that the river at B, during a rise of three feet, is at the same elevation as at A, which is not the case. And near twenty-three feet of the whole fall at low water, is employed in the descent of the Canal, or in the wheels, which will leave them submerged, frequently more than ten months in the year, and occasionally, the whole year through. Hence, the dimensions that have been determined are less than would be required in practice, with a fall of twenty-three feet; and the fall employed, is greater than the convenience and permanency in the operations of the machinery would admit.

But the dimensions of the canal from *b* to K, are calculated to convey the necessary quantity of water with 1½ foot velocity per second when the rise in the river is 3 feet above the falls, and 12 feet below, with 14½ feet head on the wheels; and the water in the canal even with the surface of the rock; consequently, if the velocity of the current is proportionably increased, the wheels may be placed 12 feet above low water mark—or higher, without any other alteration in the dimensions of the canal from b to K, or from A to *b*, except an increase in the descent, corresponding to the increased velocity which may be required. The additional excavation of rock, would

be in some degree compensated on this line, by an equal diminution of earth above it; for the whole area of the transversive section would remain nearly the same as before. A considerable increase, however, in the quantity of earth to be excavated, would be necessary from K to L, because the canal is calculated, in the whole of that distance, to convey no more water than is necessary for the greatest practicable head on the wheels which the site affords at low water, viz: twenty-three feet. But the cost would, in this case, be far more than counterbalanced by the advantages. It is not necessary, however, to go into the investigation, the present object being merely to find the minimum excavation of an adequate Canal, for the greatest head which can be employed with any security or convenience; or rather, a limit, known to be less than the truth, yet as near to it as may be safely attempted: which, it is believed, has been done.

Site below Shippingport, Falls of Ohio.

EXCAVATIONS.

Plan S—Profile No. 1.

ROCK.

1. From *A* to *b* = 2,320 feet—through bare rock.

1. Depth of the column of water at low stage of the river = 4.0 feet.
Average depth from the surface of the rock to the level of water - - - - - - - - - = 0.5
Half the descent in the bottom of the canal fom *A* to *b* = 0.25

Mean depth of the excavation - - - - = 4.75
The breadth of the canal as before determined - 11.0

52.25

4.75 × 11 × 2,320 = 121,220 cubic feet.

40,406.66

4,489.62 cubic yards.

2. From *b* to *K* = 7,672 feet, average depth above the rock - - - - - - - - - = 16.72

1. Descent in bottom of canal from *A* to *b* - = 0.5 feet.
2. Half the descent from *b* to *K* - - - = 0.5
3. Estimated least depth of water in the canal = 4.0
4. Average depth of rock above the level of low water = 2.73

Mean depth of the excavation - - = 7.73

The breadth of the canal before determined, is 12.74 feet.
$7.73 \times 12.74 \times 7,672 = 755,540$ cubic feet,
or 27,982.96 cubic yards.

Site below Shippingport Falls of Ohio.

EXCAVATIONS.

Plan S—Profile No. 1.

EARTH.

1. From *b* to *K* = 7,672 feet.
1. Breadth of the mean transverse section at bottom; or on top of rock - - - - - - = 28.5
2. Breadth at surface of the water, when the head on the wheels is four feet - - - - - = 48.0

$\frac{48.+28.5}{2} = 38.25$ feet, the mean breadth of the mean transverse section, between the surface of the water in the canal and surface of the rock.

Mean depth of this portion of the section - - = 6.5 feet.
$38.25 \times 6.5 = 248.625$ square feet the area.

2. From surface of water in canal, to surface of the ground—base of the slopes being equal to their altitude.
1. Breadth at surface of water as above - - = 48.0
2. Breadth at surface of ground - - - = 68.44
3. Depth from surface of the ground to the water = 10.22

$\frac{48+68.44}{2} = 58.22$ feet = the mean breadth above the water.

$58.22 \times 10.22 = 595$ square feet the area.
$595+248.625 = 843.625$ square feet, which is the area of the whole section from surface of the ground to the rock.

Site below Shippingport, Falls of Ohio.

EXCAVATIONS.

From *b* to *K* = 7,672 feet, continued.

Plan S—Profile No. 1.

Area of the mean transverse section above the rock = 843.625 sq. ft.
$843.625 \times 7,672 = 6,472,290.95$ cubic feet, equal to 239,714 cubic yards.

Site below Shippingport.

EXCAVATIONS—EARTH.

From *K* to *L* = 858 feet.

The canal in this distance will be walled on the side next the river: the opposite side will be of earth.

The base of the talus to the wall is $\frac{1}{8}$th its height.

The base of the slope to earth bank opposite, is one and a half times its altitude from the bottom of the canal to the surface of the water, and from thence to the surface of the ground, the base will be equal to the altitude.

For greater convenience, the area of the transverse section will be estimated in two parts.

1. Between a perpendicular, raised from the inner edge of the foundation of the wall to the surface of the ground and the opposite bank. The average height of the ground above low water mark = 20.66 feet.

Average depth below low water - - - - - 5.5

Making the whole depth - - - - = 26.16

$\frac{26.16}{4}$ = 6.56 feet, mean thickness of the wall down.

$\frac{26.16}{8}$ = 3.28 feet, the base of the talus.

$6.56 + \frac{3.28}{2} = 8.2$ feet, the thickness of the wall at its base.

8.2+1.5 = 9.7 feet, the breadth of the foundation of the wall.

13.191 feet, is the breadth of the canal at bottom.

$13.191 - \frac{1.5}{2} = 12.441$ feet, the distance between the perpendicular at the edge of foundation and the base of the slope, to the opposite bank.

14 feet is the depth from the surface of the water when there is 4 feet head on the wheels, to the bottom of the canal; therefore,

$\frac{3 \times 14}{2} + 12.441 = 33.441$ = breadth of the excavation at the surface of the water.

$\frac{33.441 + 12.441}{2} = 22.941$ = the mean breadth and

$22.941 \times 14 = 321.174$ = square feet, the area of the section from surface of the water to the bottom of the canal.

From the surface of the water to the surface of the ground is 26.16—14 = 12.16 feet;—the base of the slope is here equal to the

height; therefore, 33.441 + 12.16 = 45.601 feet, the breadth of the section at the surface of the ground.

$$\frac{45.601 + 33.441}{2} \times 12.16 = 480.575 \text{ square feet the area.}$$

480.575 + 321.174 = 801.749 square feet, the area of the whole section.

Second part of the transverse section of the canal, viz. between the perpendicular and the bank next the river including the space occupied by the wall.

Depth from surface of ground to bottom of canal = 26.16 feet.
Depth of foundation of the wall - - - 3.50

Whole depth - - - - - = 29.66 feet.
The breadth of the foundation is - - - 9.7 feet.
The base of the slope to the bank is only half its altitude.

$$\frac{29.66}{2} + 9.7 = 24.53 \text{ feet breadth of the excavation at top.}$$

$$\frac{24.53 + 9.7}{2} = 17.16 \text{ feet the mean breadth.}$$

17.16 × 29.66 = 508.9656 square feet for the area.
508.965
801.749

1310.714 square feet for the whole.

Area of the mean transverse section.
1310.714 × 858 = 1,124,592.61 cubic feet, or
41,651.5 cubic yards.
This does not include the small solid at the end of the canal.

RECAPITULATION.

Earth to be excavated from b to K = 239,714 cubic yards, averaging - - - - - - 16.72 feet.
From K to L = 41,651 averaging 28 feet.

Total excavation of earth = 281,365 cubic yards.

Site below Shippingport, Falls of Ohio.

MASONRY.

Side wall of canal from K to L, including end wall. The end wall of the canal will be estimated to have the same dimensions with the side wall. The depth from the surface of the ground to the bottom of the canal at its end, is indeed near seven feet greater

than the average depth from K to L. This difference, however, will be considered as compensated by the diminished thickness of that portion of the end wall which extends into the slope of the earth bank of the canal. The length of the end wall will be equal to the breadth of the canal at the surface of the ground, added to the breadth of the foundation of the wall.

$$\frac{35.945+12.16+12.16}{8} = 49.675 \text{ feet.}$$

858+49.675 = 907.6 feet, for the whole length of the wall.

Breadth of the foundation = 9.7 feet.

Depth of foundation = 3.5 feet.

3.5 × 9.7 = 33.95 square feet, the area of the transverse section of the foundation.

Mean thickness of the wall above the foundation = 6.56 feet.

Mean height of the wall - - - = 26.16 feet.

26.16 × 6.56 = 171.6 feet, nearly the area of the transverse section above the foundation.

33.95 square feet; area of transverse section if found above.

171.6 square feet; area of section of the wall above foundation.

205.55 square feet; whole area of mean transverse section, including foundation.

205.55 × 907.60 = 186,557.18 cubic feet.

205.55

4538.00
4538.00
4538.00
1815.20

24.75) 186557.1800 (7541.7 perches.
17325

13307
12375

10321
9900

4218
2475

17430

Deduct for four forebays, viz. 3 of 8 feet each } 168.85
1 of 4 feet }

7372.85 perches.

Site between Louisville and Shippingport.

[*Eight feet head and fall.*]

PLAN L. 2.—PROFILE No. 3.

It is proposed to ascertain the minimum dimensions of a canal, that will furnish this site with the necessary quantity of water for a head of four feet on the wheels, when the river is at its lowest stage.

Six or seven inches must, of necessity, be left to free the wheels from tail water; otherwise, the effective head on the wheels will be diminished to that extent, and the canal will no longer supply the required quantity for the reduced head.

The whole fall, therefore, which may be employed to give velocity to the water in the canal, cannot be practically greater than forty-one or forty-two inches.

If this fall is distributed between A, S, and S, Z, with a view to the least expense in the excavation, it will afford a velocity of three feet per second from A to S; and 4.3 feet per second from S to Z, nearly; and the descent will be 12.32 inches, and 28.84 inches, in those distances, respectively. Allowing a small extension (in estimating the velocity) to that portion of the perimeter in contact with the column of water in motion, for irregularities, &c. the excavations will then be as follow:

1. ROCK.

1. From A to S . distance = 3,175 feet.

Velocity 3 feet per second — 12.32 inches descent = 1.0 26.

Four feet head on the wheels; 516 cubic feet of water required; 4 feet least depth of water in this distance. As nearly the whole transverse section of the canal through this rock plane will be occupied by the column of water, the depth cannot be increased without also increasing the expense.

$$\frac{516}{3 \times 4} = 43 \text{ feet} = \text{the breadth of the canal.}$$

	feet.
Average height of rock above the level of low water, -	0.5
Half the descent from A to S, - - - -	0.513
Least depth of water in canal, - - - -	4.
Mean depth of excavation, - - - - =	5.013

Or 5 feet nearly.

13

$43 \times 5 \times 3175 = 682{,}625$ cubic feet.

227,541.6

25,282.4 cubic yards; averaging 5 feet deep.

2. From S to V = 3,581 feet.

516 cubic feet of water required.
4.3 feet per second velocity.
Descent from S to V = 28.84 — 4.25 = 24.59 inches.

	2.04 feet.	*feet.*
1. Average depth of rock above level of low water,	-	= 4.5
2. Descent in canal from A to S,	- -	= 1.027
3. Half the descent from S to V = $\frac{2.04}{2}$	- -	= 1.002
4. Least depth of water in canal from S to V	- -	= 7.0
Mean depth of excavation,	- - -	= 13.547

$\frac{516}{4.3 \times 7}$ = 17.14 feet, nearly = breadth of canal through the rock.

$13.5 \times 17.14 \times 3581 = 828\ 607.59$ cubic feet.

276,202.53

30,689.1 cubic yards.

3. From V to Z at end of canal = 620 feet.

4.3 feet velocity per second.
Descent 4.25 inches = .355 nearly.

1. Average depth of rock above level of low water	= 1.55
2. Descent from A to V = $\frac{24.59+12.32}{12}$ -	= 3.07 nearly.
3. Half the descent from V to Z, $\frac{355}{2}$ - -	= 0.177
4. Least depth of water in canal, - - -	= 7.0
	11.797

Breadth of canal = 17.14 feet.
$11.79 \times 17.14 \times 620 = 125{,}289.9$ cubic feet.

41,763.3

4,640.3 cubic yards.

Averaging 11.79 feet deep, under 29.5 feet of superincumbent earth.

Excavations.

Earth.

1. From S to V = 3,581 feet.

1. Average depth of earth to surface of rock = 17.14 feet.
17.14 feet = width of canal through the rock from S to V.
2.86 feet, added for two berms at the base of the slopes.

22.00 feet = mean width of excavation at surface of the rock.

The base to the slopes of the earth banks of the canal, is one and a half times their altitude.

$17.14 \times 3 + 20 = 71.42$ feet, the width of the canal at surface of the ground.

$\frac{71.42+20}{2} = 45.71$ feet, the mean width of the mean transverse section.

$17.14 \times 45.71 \times 3581 = 2{,}805{,}594.9$ cubic feet.

935,193.3

103,910.9 cubic yards.

Averaging 17.14 feet deep.

2. From V to Z = 620 feet.

1. Average depth of earth from surface of the ground to surface of the rock, - - } = 29.5

From V to Z, is the distance occupied by the water-shops; and a side wall next the river is required as in all other cases. The opposite bank of the canal will be left in its natural state, with a slope of one and a half times its altitude.

$\frac{29.5}{4} = 7.375$ feet, or 7.3 nearly = the mean thickness of the side wall.

$7.3 + \frac{7.3}{4} = 9.1$ feet thickness of wall at its base.

The base to the slope of the bank next the wall, is only one half its altitude.

The berm at the base of the side wall is 4 feet, and at the base of the bank opposite 1.5 foot nearly. The breadth of the excavation through the rock is 17.14 as before.

Hence, the width of the excavation at bottom, or at the surface of the rock, becomes

$17.14+9.1+4+1.5 = 31.74$ feet. And the width at the surface of ground,

$$31.74+\frac{3\times29.5}{2}+\frac{29.5}{2}=90.74 \text{ feet.}$$

$$\frac{90.74+31.74}{2}=61.24$$ feet for the mean breadth of the solid to be excavated.

And, $61.24\times29.5=1806.58$ square feet for its area.

If to the distance from V to Z $=620$ feet, is added the mean width of the transverse section of the space to be excavated for the end wall, it will give the whole length of the solid to be excavated, from V to the end of the canal, sufficiently near.

The end wall will be higher and thicker at its base than the mean section of the side wall; because the rock is presumed to be somewhat lower at that point. Assuming it to be the same,

And $9.1+\frac{29.5}{4}=16.4$ nearly for the breadth of the transverse section, embracing the wall, and the earth to be excavated back of it,

$620+16.4=636.4$ for the whole length of the solid.

$636.4\times1806.58=1149707.51$ cubic feet.

383235.83

42581.75 cubic yards—Averaging 29.5 ft. deep.

Masonry.

1. From V to Z $=620$ feet $=$ length of side wall.

If the length of end wall is taken equal to the mean width of the canal, including the side wall, the area of its transverse section will be equal to the area of the section of the side wall, nearly.

$$9.1+4+17.14+\frac{29.3}{4}=53,84$$ feet for the length of end wall.

$620+53.84=673.84$ whole length of wall to be computed.

$7.3\times29.5\times673.84=145841.44$ cubic feet; or 5892.58 perches.

From which deduct for 4 forebays, viz: 3 of 8 feet wide, and one of 4 feet wide } 103.23

5789.35 perches.

Plan L—Profile, No. 2.

Excavations.

1.—Rock.

1. From A to S = 3175 feet. Descent at 5 = 5.11 inches.
Average height of rock above low water, at A - = 0.5 feet.

Half the descent of the canal from A to S $\frac{5.11}{2}$ = 2.55 in. = 0.21

Least depth of water in the canal = 4.0

Average depth of excavation - - = 4.71 ft.
Breadth of canal - - - = 64.4 ft.

4.71 × 64.4 × 3175 = 963053.7 cubic feet: or 35,668.6 cubic yds.

6.4.4
1884
1884
2826
303.324
3715

303.324
3175
1516620
2123268
303324
909972

3)963053.700

9)321017.9

35668.6 = cubic yards.

2. From S to V = 3581.8 feet. Descent from S to V.
= 12.15—1.795 = 10.35 inches, nearly
1.795
10.355

1. Average height of the rock on this line above low water, at A - - - - = 4.5 feet
2. Descent from A to S of the canal = 5.11 inches = 0.425
3. Half the descent from S to V = $\frac{10.35}{2}$ = 5.17 = 0.426
4. Least depth of water in the canal = 7.0

Average depth of excavation - = 12.351
Breadth of canal - - - = 24.58

24.58 × 12.35 × 3581.8 = 1,087,304.414 cubic feet: or

362,434.8

40,270.5 cubic yards.

From V to Z = 620 feet. Descent from V to Z = 1.795 inches.

1. Average height of the rock on this line above low water level at A - - - - = 1.55 ft.
2. Descent of canal from A to V = 10.35 + 5.11 = 15.47 inches, nearly - - - - = 1.29 nearly
3. Half the descent from V to Z = $\frac{1.79}{2}$ = .84 of an inch, nearly - - - - = 0.07
4. Least depth of water in canal - - = 7.0

Average depth of excavation - = 9.91 feet
Breadth of canal - - - = 24.58

9.91 × 24.58 × 620 = 151.024.4360 cubic feet: or 5593.497 cubic yards.

Recapitulation of Rock Excavations.

1. From A to S—less than five feet deep = 35 668.6 cubic yards
2. From S to V = 40270.53 } averaging 11 feet deep, under an aver-
3. From V to Z 5593.49 } age depth of 19 feet of earth.

45864.02

EXCAVATIONS OF EARTH.

1. From S to V = 3581 feet.

1. Average depth of earth to the rock in this distance = 17.14 feet.
2. Width of canal through the rock from S to V = 24.9
3. Add for two berms of the base of each talus = 2.85

Mean breadth of excavation at bottom = 27.75 feet.

17.14 × 3 × 27.75 = 79.17 feet, for the breadth of the excavation at the surface of the ground.

$\frac{79.17 \times 27.75}{2}$ = 53.46 feet for the mean breadth of the mean transverse section.

Therefore, 53.46 × 17.14 × 3581 = 3,281,270 cubic feet: or

9)1093756.66

121528.5 = cubic yards.

2. From V to Z = 620 feet.

Average depth of earth above the surface of the rock in this distance - - - - = 29.5 feet

$\frac{29.5}{4}$ = 7.375 feet = mean thickness of the side wall.

1.843 feet = half the talus.

9.218 feet = the thickness of the wall at its base on the rock.

The canal will have but one side walled. The base of the slope to the earth will then be half its altitude on the side next the wall; and one and a half times its altitude for the opposite side. Again: the breadth of the canal, through the rock, is 24.58 feet, as before, from S to V: to which must be added, a berm of three feet at the base of the wall, and two feet at the base of the slope, to the side, opposite which is of earth. Hence, the breadth of the excavation of earth at bottom, or at the surface of the rock, becomes:

24.58 + 9.218 + 3 + 2 = 38.798 feet.

Its breadth at the surface of the ground is,

$$38.798 \times \frac{29.5}{2} + \frac{29.5 \times 3}{2} = 97.798 \text{ feet.}$$

And the mean breadth of the mean transverse section,

38.798 + 97.798 = 68.298 feet.

The prism, to be excavated at the end of the canal, will have $\frac{29.5}{4}$ + 9.218 = 16.593 feet, nearly, for the mean breadth of its transverse section; which must be added to the distance from V to Z, in order to include the whole quantity of earth to be excavated, nearly.

Then, 620 + 16.593 = 636.593 feet, the whole length of the solid: and,

68.298 × 29.5 × 636.59 = 1282595.16 cubic feet

427531.7

47503. cubic yards

Averaging 29.5 feet deep.

Recapitulation of the excavations of earth.

121,528 cubic yards, from S to V, averaging 17.14 feet deep, at 20 cents per cubic yard.

47,503 cubic yards, from V to Z, averaging 29.5 feet deep, at 30 cents per cubic yard.

Masonry of Canal.

Plan L—Profile No. 2.

1. From V to Z = 620 feet.

If the mean width of the canal below the top of the wall is added to the thickness of the wall at its base, the sum will be equal, very nearly, to the mean length of the end wall, computing it to have the same mean transverse section with the side wall, viz.

$$38.798 + \frac{3 \times 29.5}{2} + 9.218 = 70.116 \text{ ft.} = \text{length of end wall.}$$

And 620 + 70 = 690 feet, nearly, for the whole length of wall.

29.5 × 7.375 = 217.5625 square feet, the area of the mean section.

217.5625 × 690 = 150118.1 cubic feet: or

6065.3 perches.

Site below Jeffersonville, Falls of Ohio.

From the lower end of Jeffersonville to *h* on plan, at the head of the proposed canal, the fall at low water is 6 inches. From *h* to low water mark opposite D, where the first water wheel will be placed, the fall is 15.83 feet; and from thence to low water mark in ths basin opposite the last water wheel, the fall is 1.4 feet: making the whole fall at this site from the head of the canal to the last water wheel 17.23 feet.

It is asserted that the rise in the basin opposite F is 2 feet, for one foot rise at Jeffersonville, counting from low water. The difference of level between those two points is 17.23 feet; therefore, when the rise at the Ohio at Jeffersonville is 7 feet, the rise in the basin is 14 feet; and the whole fall or difference of level at that time is 17.23+7—14=10.23 feet. Also, the basin opposite F, is near 7 feet above the level of low water at Shippingport.

Now, according to Mr. Berthoud's observations, when the rise of the Ohio at Louisville is 7 feet, the rise at Shippingport is 24 feet, and the whole fall in the river between those two places at that time is only 7 feet; there is then an error in the statement of the ratio, between the rise of the river at Jeffersonville and at the basin referred to.

The fall which really exists between those points at any one stage of the river above low water, must obviously be a less portion of the whole fall between Louisville and Shippingport at that time, than it is during low water. Indeed, when the river is more than ordinarily high, the descent between any two points, must be to the

whole descent from the head to the foot of the falls, nearly as the distances. If the fall from *h* to F. at any given elevation of the river above its low stage, is supposed to bear the same ratio to the whole fall between Louisville and Shippingport at that time, which it does at low water, viz. 17-23::24, it will exceed the truth. Hence when the rise at Jeffersonville is 5 feet, the rise at Shippingport 18.5 feet, and the difference of level between Louisville and Shippingport 10.5 feet, the difference of level between *h* and F must be less than 7.54, which is the ratio, nearly. If then 7¼ feet is taken as the fall from *h* to the last water shop, when the rise is 5 feet at *h*, it will probably still exceed the truth. From *h* to where the proposed canal will enter the river bank at *a*, is a rock plane, bare at low water, and of an average elevation of 1.75 feet above low water at *h*. From *a*, to the end of the canal, the rock has an estimated average elevation of 4 feet above low water level at *h*; and from *a*, to where the side of the canal next the river will be walled at D, the average elevation is nearly 5 feet.

From D to the end of the canal, the rock averages less than 4 feet above low water at *h*; the side next the river will be walled; and as the canal will preserve its whole breadth from that point to the last water shop, and as the quantity of water conveyed per second diminishes continually after passing D, while the space occupied by it remains the same, no variation of the velocity of the water will be estimated on account of the diminished height of the rock.

Since the whole length of this canal will have its bottom and sides to the height of 10 or 12 feet of rock, any required velocity may be given to the current at low water, and all deposition in the canal speedily and safely removed: a much greater velocity may also be permitted, when it is in contact with the earth slopes of the canal above the surface of the rock, than would be admissible under almost any other circumstances than those described. Two feet may be allowed, without immediate hazard to the banks of the canal, when the water is even with the surface of the rock. A berm of two feet on each side, together with the talus to the sides, will reduce this velocity at the period when there is four feet head or less on the wheels. The dimensions of the canal will then approach to what are deemed the least that are practicable, consistent with economy and convenience in any case.

The object of this investigation is not to prove what is the absolute minimum cost of a canal which may barely supply the requisite quantity of water, without reference to the convenience of the works, but to ascertain as near as may be done, the dimensions that are necessary to improve whatever advantages the site may offer, with the least hazard of obstruction to the machinery. Now, the head which exists at that stage of the river when the water first comes in contact with the earth slopes of the canal, is also the greatest which can be advantageously employed when the river is at its lowest stage, and will therefore govern the dimensions and descent

of the canal. If the wheels were placed much lower than this limit, they would not only be longer under water, but the head employed on them being greater, they would necessarily be much more liable to accidents, more difficult to repair, and in some instances it would be altogether impracticable, until they should be nearly uncovered by the receding of the river. Besides, the power is already separated from the weight, more than 40 feet; and this distance would be increased, and with it a serious objection to the site, without any corresponding benefit to the works, and but comparatively trifling economy in the excavations.

Site near Jeffersonville, Falls of Ohio.

Plan J. *Profile* R. B.

From N to H, (prof. R B) is 2178 feet through bare rock, which averages only 1.75 feet above low water. The velocity might be increased at pleasure in this distance; but it is to be observed, that the average depth of the excavation is less than six feet, and the cost per cubic yard will therefore not exceed 75 cents. That the descent employed between N and H, is added to the depth of the excavation from H to the end of the canal. That in this last distance the rock will average 11.34 feet above the bottom of the canal, with an average of 19 feet of superincumbent earth, and 24 feet between D and I; which doubles the cost of excavating each cubic yard. Therefore, to equilibrate the expense of these excavations, and also to lessen the disadvantage to the works, of employing a greater descent, the velocity from N to H will be limited to 4 feet per second, the depth of the canal being given = 4 feet, the breadth becomes 17.31 feet, and the descent 1.2 feet, including the descent from R to N.

Site below Jeffersonville.

Plan J. Profile R B.

From H to I, (profile R B) is 2028.84 feet. The average depth of the rock has been stated at four feet above the level of low water; and when the rise of the river at *h*, (plan —) is five feet, the water in the Canal will be even with its surface. The head on the wheels will then be, at most, 7¼ feet; the least quantity of water required, 285 cubic feet; and the velocity of the current, about two feet per second. The least dimensions of a canal, which will conform to these conditions, and supply an equal quantity of water, during the low stage of the river, the head on the wheels being also 7¼ feet, must admit near

five feet depth of water at that time, with a velocity of five feet per second, which gives a breadth of twelve feet, and requires a descent from H to I, of 2.24 feet, nearly.

Site below Jeffersonville, Falls of Ohio.

CANAL EXCAVATIONS.

$7\frac{1}{4}$ feet head on the wheels, at low water.
285 cubic feet of water required.

ROCK.

PLAN J PROFILE R B.

1. From R, at the head of the Canal, to N = 333.3 feet at the head of the Canal, the river is only three feet deep. The breadth of the column of water must therefore be $\frac{285}{3 \times 4}$ = 23.75 feet, the velocity being 4 feet per second.

The breadth of the canal at N is 17.81 feet, and depth 4 feet.

Supposing the surface of the rock to slope uniformly from N to R, which is nearly the case, its section in the direction of its length, will be a triangle, having its base 4 feet, and perpendicular 333.3 feet. The whole solid to be excavated, will be equal to half of a prism of those dimensions, and 17.81 feet broad; and a triangular pyramid, containing less than 100 cubic yards.

1. Breadth of Canal at N - - -	= 17.81 feet.
Add incidental obstructions, &c. - -	2.19
Total breadth,	= 20.

$\frac{20 \times 3 \times 333.3}{2}$ = 19998. cubic feet = 740.6 cubic yards.

To which add for the pyramid, = 95.

Total excavation from R to N, = 835.6 cubic yards.

2. From N to H, = 2178 feet.

1. Average depth of rock above the level of low water,	= 1.75 feet.
2. Depth of water in the Canal, - - - - -	= 4.0
3. Half the descent from N to H, added to the whole descent from R to N, - - - - -	= 0.68
Whole depth of excavation,	= 6.43

Here, as between R N, the allowance for obstructions, &c. will be made by increasing the breadth of the transverse section, as the least expensive, which will be taken as before, at 20 feet.

$6.43 \times 20 \times 2178 = 280090.8$ cubic feet,
or, $= 10,373.7$ cubic yards.

3. From H to I, = 2028.84 feet.

PROFILE R B.

1. Average depth of rock above the level of low water,		= 4.0 ft.
2. Descent from R to H,		= 1.2
3. Half the descent from H to I,		= 1.14
3. Least depth of water in Canal,		= 5.0
Whole depth of excavation,		= 11.34 ft.

The velocity is 5 feet per second, and the breadth of the Canal, 12 feet. The same considerations do not hold, in enlarging the dimensions of the Canal from H to F, as before, from R to H, and no allowance is made.

From H to I, = 2028.84 feet.

PROFILE R B.

$11.34 \times 12 = 136.08$ feet = area of the section, and $136.08 \times 2028.84 = 276084.54$ cubic feet, or 10225.3 cubic yards.

Site near Jeffersonville.

CANAL EXCAVATIONS

Of Earth.

1. From H to D, where the first water is placed, = 1,408.8 feet

1. Breadth of canal, through the rock,		= 12
2. Breadth of two beams, one on each side, 1½ foot each,		= 3
Breadth of excavation at surface of rock,		= 15
Average depth of earth above the rock,		= 17

The base of the slope of each bank of the canal is one and half times the height: consequently,

$3 \times 17 \times 15 = 66$ feet for the breadth of the excavation at the surface of the ground; and

$\frac{66 + 15}{2} = 40.5$ feet for the mean breadth of the mean transverse section; therefore,

$40.5 \times 17 = 688.5$ square feet for the area, and
$688.5 \times 1408.8 = 969958.8$ cubic feet, or
35924.4 cubic yards.

Site near Jeffersonville, Falls of Ohio.

CANAL EXCAVATIONS.

7¼ feet head on the wheels.
285 cubic feet of water required.

Of Earth.

2d. From D to I, at end of canal, 620 feet.
Mean depth of earth, from the surface of the ground to the rock, = 24 feet, which is, also, the height of the side wall, from D to I.

$\frac{24}{4}$ = 6 feet the mean thickness of the wall

1.5 feet = half the base of the talus
7.5 feet = breadth of the wall at is base.

The depth of the cutting, through the rock, from D to I, averages 11.34 feet. The sides are perpendicular; and the mean velocity of the current is five feet per second.

The security of the wall, therefore, will require it to be placed about four feet from the edge of the rock, which will be sufficient to ensure it against the effects of the current, with the velocity it would have in case any portion of the intermediate rock should be worn or sapped by its action.

The berm, at the base of the slope on the side of the canal opposite to the wall, will remain, as before, = 1.5 feet.

The breadth of the canal, through the rock, = 12.0 feet; therefore, 12+4+1.5+7.5 = 25 feet for the breadth of the excavation of earth at the surface of the rock.

The base, to the slope of the earth on the side where the wall is to be placed, need not exceed what is barely necessary to sustain the bank while the walls are erecting: half the height is sufficient for that purpose. The base of the slope on the opposite side continues to be one and a half times the whole height.

$\frac{24}{2} + 25 + \frac{3 \times 24}{2}$ = 73 feet for the breadth of the excavation at the surface of the ground.

$\frac{73+25}{2}$ = 49 feet for the mean breadth of the excavation; and

49 × 24 = 1176 the area;
1176 × 620 = 729,120 cubic feet, or
27,004 cubic yards,
Averaging 24 feet deep.

3d. Excavation of earth, at the end of canal, not included in the foregoing estimate.

This excavation will consist of a prism and two pyramids. The mean breadth of the transverse section of the prism is equal to one half the sum of twice the breadth of the wall at its base, added to half its height, viz:

$$\frac{7.5\times 2+12}{2}=\frac{27}{2}=13.5 \text{ feet.}$$

The length of this solid is equal to the length of the end wall of the canal added to the breadth of the wall at its base, viz:

41.5+7.5 = 49 feet

24 feet, the depth of earth above the surface of the rock

$49\times 24\times 13.5 = 15876$ cubic feet.

5292

588 cubic yards.

The several small solids, at the angles, are omitted, is inconsiderable.

RECAPITULATION.

Excavation of earth—	1. From H to D,	- -	= 35924.4
	2. From D to I,	- -	= 27004.0
	3. At end of canal,	- -	= 588.0
	Total excavation of earth,		= 63516.4

Masonry of the Canal.

Plan J—Profile R. B.

From D to I, at end of canal, = 620 feet.

The end wall of the canal will be the same average height as the side wall. Its whole length will be equal to the width of the canal at the surface of the ground. added to the thickness of the wall at top; but that portion of it which extends into the slope of the earth, will necessarily diminish, in its breadth, to less than half its former mean thickness. The whole length of this wall will, therefore, be taken equal to the *mean* width of the canal, having the same transverse section as the side wall.

Mean width of canal, including the thickness of the wall, viz:

$12+4+\frac{24\times 3}{4}+7.5 = 41.5$ feet, which is the length of the end wall nearly.

620+41.5 = 661.5 feet length of wall having the same transverse section.

Height of the wall, = 24 feet
Mean thickness, = 6 feet
6 × 24 = 144 square feet for the area,
144 × 661.5 = 95256 cubic feet, or
3848.7 perches.

Deduct for 4 forebays, viz.
3 of 8 feet wide each, } 70.47
1 of 4 feet, }

3778.23 perches.

Site at North Bend, on the Ohio River.

38.62 feet: difference of level between low water of the Miami river, at the mouth of Jordon's Creek, and low water of the Ohio, at North Bend.
10.0 feet: height of proposed dam on the Miami, near Jordan's Creek.

48.62 feet: whole fall, or difference of level between low water of the Miami, above the dam, and low water of the Ohio.

The forge will be included in the estimates for this site. The power required is 1032. The greatest head employed on the wheels is 15 feet. The corresponding quantity of water is 138 cubic feet per second. The least efficient head will be four feet; and the quantity of water, then required, 516 cubic feet.

Excavations of the Canal.

Plan N—Profile C. R.

EARTH.

1. From C, at the head of the canal, to B, at the head of the tunnel, is 9270.36 feet.

In the whole of this distance, the canal passes through a level river bottom. The mean velocity of its current will, therefore, not exceed twelve inches per second.

1. Average height of the surface of the ground, above the level of the dam, = 11.62

The width of the canal, at its bottom, will, in this case, be equal to the depth of water which it contains during the lowest stage of the Miami; therefore, $\frac{\sqrt{138 \times 2}}{5} = \sqrt{55.2} = 7.43$ feet nearly. The least depth of water in the canal, and least width

of its bottom, which should be augmented to 8 feet to allow for impediments and obstructions of all kinds. Then,

$8+11.62 = 19.62$ feet: whole depth of earth to be excavated.

$3\times19.62+8 = 66.86$ feet: breadth of canal at surface of the ground.

$\frac{66.86+8}{2} = 37.43$ feet: mean width of mean transverse section of canal.

And, $37.43\times19.62\times9270.36=6807929.89$ cubic feet

2269309.96

252145.55 cubic yards

of earth to be excavated, averaging 19.62 feet from surface of the ground to bottom of canal.

Tunnel.

From B. at the entrance of the tunnel into the hill, to its outlet at a point corresponding to L, in the ravine, (profile C R) the distance is 1817 feet nearly.

The velocity of the current through the tunnel, cannot exceed 4 feet per second, when the head on the wheels is 4 feet, without giving a greater depth to the column of water when the head is 15 feet, and the Miami at is lowest stage, than would otherwise be necessary or expedient: and requiring a greater descent than would, in all probability, be compensated by the difference, if any, in the cost of the excavation.

When the head is 4 feet on the wheels, the quantity of water required, is 516 cubic feet per second. Therefore, the least dimensions of the transverse section of the tunnel that will convey this quantity with a velocity of 4 feet per second, will be nearly a square; of which $\frac{\sqrt{516}}{4}=\sqrt{129}=11.35$ feet, is the length of one of its sides.

If the bottom of the tunnel is placed 4½ feet below the level of the dam, the same descent that will give a velocity of 4 feet to the current when the depth of the column of water is 11.35 feet, will also be amply sufficient at the lowest stage of the Miami, to give the requisite velocity when the head on the wheels is 15 feet.

Hence, the bottom of the tunnel, and the top of its roof, will have the same inclination; and the descent employed, will not add to, or effect the excavations.

It will be proper, however, to give a greater elevation to the roof than what is assigned to the surface of the column of water: both to avoid an increased resistance to the current and consequent augmentation of the descent, as well as to secure the roof from the long continued action of the water when the velocity is 4 feet per second.

The whole height will then be assumed at 13 feet, or 1.64 feet above the surface of the water, when the Miami is between 6 and 7 feet on the dam, and 4 feet head on the wheels;

then: $11.36 \times 13 \times 1816 = 268186.88$ cubic feet

89395.62

9932.07 cubic yards.

This estimate is based upon the supposition that the tunnel will pass entirely through solid rock; and that no additional excavation will be required on account of shafts and arches.

Excavations of Earth.

3. From the end of the tunnel at a point corresponding to L, in the ravine, (prof. C. R.) to the first water shop at a point corresponding to H, (prof. C. R.) is 4 chains nearly, on a straight line=264 feet.

The dimensions of the canal below the level of low water, will here be the same as those assigned to it from C, to the head of the tunnel.

1. Supposed average depth of earth above the level of the dam, - - - - - =15.0 feet
2. Least depth of water in canal, including an allowance for probable obstructions, - - =8.0 feet
3. Whole descent from head of canal to L, - =1.0 nearly

Mean depth of earth to be excavated. =24.0

$\frac{3 \times 24}{2} + 8 = 44$ feet, mean width of mean transverse section of canal.

$44 \times 24 \times 264 = 278784$ cubic feet

92961.3

10317.9 cubic yards averaging 24 feet deep.

4. From H on plan N, (corresponding to H on prof. C. R.) to the last water shop at E, is 620 feet.

1. Average depth of earth above the level of the dam, =10.0 feet
2. Least depth of water in canal below the level of the dam, (including allowance for obstructions,) = 7.0 feet
3. Descent of canal, - - - - = 1.0 nearly,

Mean depth of the bottom of the canal below the surface of the ground, - - - = 18.0

$\frac{18}{4} = 4.5$ feet, mean thickness of side wall.

$4.5 + \frac{4.5}{4} = 5.625$ feet, thickness of wall at its base.

$5.625 + 1.75 = 7.375$ feet, width of the foundation.

3 feet, depth of the foundation.

Then $\frac{138}{6.5} = 21.23$ feet, mean width of the column of water at its lowest stage.

$21.23 - \frac{6.5 \times 3}{4} - \frac{6.5}{16} = 15.96$ feet nearly, least width of the column of water at bottom.

$15.96 + .5 = 16.46$, or 16.5 feet nearly, width of canal at bottom.

$16.5 - .75 = 15.75$ feet, width from the inner edge of the foundation of the side wall to the base of the opposite bank of the canal.

$15.75 + \frac{3 \times 18}{2} = 42.75$ feet, mean width of the solid contained between a perpendicular, raised from the inner edge of the foundation of the wall to the surface of the ground and opposite bank of the canal.

$42.75 \times 18 = 769.5$ square feet, area of its transverse section.

Again. $18 + 3 = 21$ feet, depth from the surface of the ground to bottom of the foundation of the side wall.

$7.37 + \frac{21}{4} = 12.62$ feet, mean width of the solid to be excavated, embracing the space to be occupied by the side wall and its foundation.

$12.62 \times 21 = 265.02$ square feet, area of its transverse section.

$769.5 + 265.02 = 1034.52$ square feet, area of the transverse section of the whole solid to be removed.

$620 + 12.62 = 632.62$ feet, the whole length of the solid.

$1034.52 \times 632.62 = 654,354.59$ cubic feet.

218,118.19

24,235.35 cubic yards.

MASONRY.

$\frac{18 \times 8}{2} + 7.375 + 16.5 = 50.875$ feet, mean length of end wall, supposing it to have the same transverse section with the side wall.

$620 + 50.875 = 670.875$ feet, whole length of wall, from which must be deducted the widths of eight forebays, viz:

Reduced to half the number. 6 forebays, 10 feet mean width, each = 60 feet.
2 forebays, 6 feet mean width, each = 12 feet.

72 feet.

670.875 — 72 = 598.875 feet length of wall to be
4.5 × 18 = 81 square feet, area of transverse section above the foundation.
7.375 × 3 = 22.125 square feet, area of transverse section of foundation.
81 + 22.125 = 103.125 square feet, area of the whole transverse section.
598.875 × 103.125 = 61,758.98 cubic feet,

or 2,495.3 perches.

Add for reduction in the number of fore-bays. 150.

2,645.3

RECAPITULATION.

1. EARTH.

252,145.5 cubic yards, averaging 19.62 feet deep.
24,235.35 cubic yards, averaging 18 feet deep.
10,317.9 cubic yards, averaging 24 feet deep.

Total 286,698.75 cubic yards of earth.
Or 252,145.5
24,235.35

276,380.85 cubic yards, averaging above 19 feet deep.
10,317.9 cubic yards, averaging 24 feet deep.

Total 286,698.75 as before.

2. ROCK.

9,932.7 cubic yards for the tunnel.

MASONRY OF CANAL.

2,495.3 perches.
150.

2,645.3

Site on Bowman's creek, near Licking river, Ky.

PLAN T—PROFILE A B.

A dam 15 feet high, across Licking river, near the mouth of Cruiser's creek, will give 8 feet fall at D, where the Canal enters the valley of Bowman's Creek. The intermediate ground is river bottom. The velocity of the current in the Canal will therefore not exceed one foot per second. The descent requisite will be too inconsiderable to affect the excavations in any material degree; and the whole fall of 8 feet, will be considered as employed on the wheels.

EXCAVATIONS.

Earth.

1. From A to D, distance 9784.5 feet. The base of the slope to the banks of the Canal, will be one and a half times their altitude; the width of the Canal at bottom, equal to half the depth of water contained in it, during the lowest stage of the river.

258 cubic feet, is the quantity of water to be delivered per second:

therefore, $\sqrt{\frac{258}{2}} = 11.357$ feet, or 11.36, the depth of the column of water.

The average depth of earth above the level of the dam, is 16.746 feet; consequently, $16.756 + 11.36 = 28.1$ feet, nearly, is the average depth of earth to be excavated on the whole route A D.

$\overline{28.1 \times 3} + \frac{11.36}{2} = 89.98$ feet, width of Canal at the surface of the ground.

$\frac{11.36}{2} = 5.68$ feet, width of Canal at bottom.

$\frac{89.98 + 5.68}{2} = 47.83$ feet, mean width of Canal, and

$47.83 \times 28.1 = 1344.023$ square feet, area of the mean transverse section, and

$1344.023 \times 9784.5 = 13150593.+$ cubic feet,

or, 487059. cubic yards: averaging 28.1 feet deep from surface of the ground to bottom of the Canal.

2. From D to B, at end of Canal, 620 feet distance. A side wall next the water shops will be required here, as in other cases.

The bottom of the Canal, in this distance, will be 7 feet below the level of the dam. A greater depth would reduce the excavation to

less than what is required for the embankment, on which to raise the work shops above the level of ordinary high water at the dam; and a less depth is not supposed to be essential.

1. Average depth of earth above the level of the dam,	3.0 feet.
2. Least depth of water in the Canal, - - -	7.0
Whole depth to be excavated,	10.0

The level of high water at the mouth of Cruiser's Creek, is 22 feet above the bottom of the Canal. A dam 15 feet high would cause the freshets of Licking to rise several feet higher at that point, and would most probably afford a head of 4 feet on the wheels at the water shops, until the river should reach the greatest elevation which it is known to have formerly attained. It would therefore be necessary to give at least an equal height to the side wall, viz: 22 feet above the bottom of the Canal.

$\frac{22}{4} = 5.5$ feet, the mean thickness of the wall.

$\frac{5.5}{4} + 5.5 = 6.875$ feet, thickness of the wall at its base.

3 feet, depth of its foundation.

And $\frac{258}{7} - \frac{3 \times 7}{4} - \frac{7}{16} = 31.169$ feet, nearly; breadth of Canal at bottom.

$31.169 - .75 = 30.419$ feet; breadth of that part of the bottom of the Canal, between the foundation of the wall and the base of the opposite bank.

$\frac{10 \times 3}{2} + 30.419 = 45.419$ feet; width of the excavation at the surface of the ground, between a perpendicular, raised from the inner side of the foundation of the wall, and the opposite side of the Canal.

$\frac{45419 + 30.419}{2} = 37.919$ feet, mean width.

$37.919 \times 10 = 379.19$ square feet; area of the transverse section.

$10 + 3 = 13$ feet, depth from the surface of the ground to the bottom of the foundation of side wall.

8.375 feet, thickness of the foundation wall.

$8.375 + \frac{13}{4} = 11.625$ feet, mean width of the transverse section.

$11.625 \times 13 = 151.125$ square feet, area of the transverse section, including the space to be occupied by the side wall and its foundation.

379.19 + 151.121 = 530.311 square feet, area of the whole transverse section of the solid to be excavated between D and the last water shop.

620 + 11.625 = 631.625 feet, whole length of the solid, including the part to be excavated on account of the end wall.

631.625 × 530.311 = 334957.68 cubic feet

or, 12405.84 cubic yards, averaging about 11 feet deep.

MASONRY.

Length of side wall from D to B at end of canal = 620 feet.
Mean height of the wall above its foundation - = 22 feet.
Mean thickness - - - - - - - = 5.5

5.5 × 22 = 121 square feet, area of the transverse section.

8.37 feet; width of the foundation.
3 feet; depth of the foundation.

8.37 × 3 = 25 11; area of the transverse section.

and 121 + 25.11 = 146.11 square feet; area of the whole transverse section of the wall including the foundation.

If the length of the end wall is taken, equal to the width of the canal at the surface of the ground; its mean transverse section will be equal to that of the side wall (nearly.) Then 620 + 47.419 = 667.419 feet, will be the whole length of the wall. From which must be deducted for eight forebays; viz:

*6 forebays, mean width each, 10.75 feet - - = 64.5 feet.
*2 forebays, mean width each, 6.75 - - = 13.5

Making - - - - - - - - 78.0 feet.

667.419 — 78 = 589.419 feet (nearly) for the length of wall to be computed.

146.11 × 589.4 = 86,118.224 cubic feet

or 3,479 perches of masonry.
add for reduction in number of forebays. 230.23
3,709.23

The length of the end wall is assumed to be equal to the width of the canal at the surface of the ground, because of the necessity of its extension in the present case, in consequence of the elevation of the high water in the canal above the surface of the adjacent grounds; at Louisville and in some other instances, the effective head on the wheels cease; before the water reaches the surface of the ground; and any further rise is supposed to be prevented by means of the head gates, or the whole establishment would be inundated.

* Reduced to half the number.

In all other cases, the canal walls extend no higher than the natural elevation of the ground.

RECAPITULATION.

1. *Excavations of Earth.*

1. From A to D = 487059 cubic yards averaging 28.1 feet deep.
2. From D to B = 12405.8 cubic yards averaging 11 feet deep.

2. *Masonry of Canal.*

From D to end of canal = 3479 perches.
Add 230.23

3709.23

Canal at Zanesville.

EXCAVATIONS OF EARTH.

1. From H I. at the end of the rock, (Plan Z, No. 3, Profile A C, to the last water shop at C.

2

Whole distance to be computed 2145 feet.
Descent of canal in that distance 0.96 feet.

1. *Between the side walls of canal.*

14.7 = mean depth of earth from surface of ground to low water level.
0.48 = half the descent from H I to end of canal.
0.72 = whole descent from head of canal to H I.
.5 = depth to be occupied by flagging.
5. 0 = depth of water when free from ice, &c.

21.38 feet = mean depth of earth to be excavated, from surface of ground to bottom of canal, contained between the foundations of the two side walls.

The velocity is 3 feet per second, when the column of water is 4.0 feet deep. The breadth of the canal is at bottom 20.25 feet; and as the foundations project 9 inches beyond the walls at each side, the excavations for which will be computed separately: the whole breadth of the space to be excavated within the side walls,

and between the foundations and surface of the ground, is 20.25 — 1.5 = 18.75 feet.

Therefore $18.75 \times 21.38 = 400.865$ square feet, for the area of the mean transverse section of the space between the walls.

2. *Of the space embracing the walls and their foundations.*

21.38 = mean depth of excavation within the walls as before.
3.0 = depth of foundations.

24.38
0.5 = depth occupied by the flagging to be deducted.

23.88 = whole depth from surface of the ground to the bottom of the foundations.

Again: Breadth of the foundations = 8 feet; and the breadth of the foundation, added to ¼ of the whole height of the wall, is equal to the mean breadth of the traperoid of which the transverse section consists.

$8 + \frac{23.88}{4} = 13.97 = 14$ feet, nearly the mean breadth.

$23.88 \times 14 = 334.33$ square feet, area of the section, embracing one side wall from the bottom of the foundation to the surface of the ground, and

$334.33 \times 2 = 668.66$ square feet, area of the two sections, including both side walls.

Hence, $400.865 + 668.66 = 1069.52$ square feet, area of the mean transverse section of the whole solid to be excavated from HI to end of canal.

$1069.5 \times 2145 = 2294120.4$ cubic feet.

764706.8

84967.4 cubic yards.

3. *Excavation at end of Canal.*

The solid to be excavated at the end of the canal, may be resolved into a prism, and two pyramids.

1. *Prism.* Its length, equal to the length of the foundation of the end wall of the canal, added to twice the breadth of the foundation.

Its transverse section is a traperoid, having the same altitude as the end wall, and a mean breadth equal to one fourth the height of the wall, added to the breadth of its foundation.

2. Two rectangular pyramids at the angles, the height of each equal to the whole depth of the excavation; and the length of the sides of the base equal to half that depth.

PRISM.

$20.25+8\times4=\overline{52.25}$ feet for the length.
12.1 = depth of ground from its surface to low water level.
0.72= equal descent from head of canal to I.
0.96= descent from I to end of canal.
5.0 = depth of water in canal.
3.0 = depth of foundation.

21.78= whole depth from surface of ground to bottom of foundation.

$21.78 \times \left[\frac{21.78}{4}+8\right]$ =292.832 square feet; area of the transverse section.

$292.8\times52.25=15298.8$ cubic feet.

2. PYRAMIDS.

21.78 feet = height.
10.89= length of each side of the base.

$\frac{10.89\times10.89\times21.78}{3}\times2=1722$ cubic feet; the —— of both pyramids.

15298
1722

17020 cubic feet.

5673

630 cubic yards to be excavated on account of end wall.

84967
630

85597 cubic yards, from H I to end of canal, including excavations for the end wall.

4. *Of the earth resting on the surface of the rock, from H I to head of Canal.*

1. From H I to B D=114.8 nearly.

1. Section at H I. (Prof. A. C.)

Feet. 2
18 = depth of earth from the surface at I, to level of low water.
0.72 descent from head of canal to I.
5.0 = least depth of water in canal.

23.72 = whole depth of earth from the surface of the ground to bottom of canal at H I.

20.75= breadth of canal at bottom.
7.41= thickness of wall at the base.

$20.75+\overline{7.41\times2}+23.72 = 59.29$ feet = breadth of the excavation at surface of the ground.

$\frac{59.29+20.75+\overline{7.41\times2}}{2} = 47.43$ feet; the mean breadth of the section.

$47.43\times23.72=1125$ square feet; the area of the section.

2. *Section at B. D.*

Feet.

17.5 = depth of earth from surface of the ground to the rock.
12.2 = breadth of canal through the rock.
12.2+3=15.2= breadth between the inner sides of the walls at their bases, including a berm 1½ foot in front of each.

$\frac{17.5}{4}+\frac{17.5}{16}=5.718+=5.72$ feet; nearly the thickness of the walls at their base.

$15.2+\overline{5.72\times2}+17.5=44.14$ feet = width of excavation at the surface of the ground.

$15.2+\overline{2\times5.72}=26.64$ feet = width of excavation at bottom, or surface of the rock.

$\frac{44.14+26.64}{2} = 35.39$ the mean breadth of the section.

$35.39\times17.5 = 619.32$ square feet the area.
Distance between H I and B D = 114.8 feet nearly.

$\frac{619.32+1125}{2}\times114.8 = 100123.96$ cubic feet.

33374.65

3708.2 cubic yards, for the content of the solid between H I and B D.

5. From B D to V W.

Distance = 380.16 feet.
Section at V W.

12.6 feet = depth of earth from surface of ground to the rock.
17. = 12.2+4.8 = distance between the inner basis of the two walls, including the two berms, which are 2.4 each, at that height.

The walls terminate at V, when they are not more than 3 feet high; but they have a bank 8 feet higher to sustain, which requires the breadth to be proportionate; 3 feet may be taken for the thickness at the base.

17+2+3 × 23 feet for the breadth of the excavation at the surface of the rock.

$23+12.6 = 35.6$ feet; breadth of excavation at surface of ground.

$\frac{23+35.6}{2} = 29.3$ feet for the mean width.

$29.3 \times 12.6 = 369.18$ square feet the area of the transverse section at V W.

619.32 = area of the section at B D, as before.

$\frac{619.32+369.18}{2} \times 380.16 = 187894$ cubic feet,

62631

6959 cubic yards, for the content of the solid contained between B D and V W.

6. From V W to head of Canal, at the whole distance. is 528 feet; but the mean distance, with 12.66 feet uniform depth of ground, is 479 feet, (nearly,) viz:

$$1023 - 380.16 + 114.84 + \frac{99}{2} = 478.5$$

The average height of the rock in this distance is supposed to be 10 feet; the surface of the ground remaining nearly the same as on the line located, of which is the profile; therefore,

$\frac{22.95+22.37}{2} - 10 = 12.66$ feet for the mean depth from surface of ground to the rock.

12.2 feet = breadth of Canal through the rock.
3.0 = two berms.

15.2 feet = breadth of excavation at bottom.

There are no walls between these two points, consequently,

$15.2 + \frac{12.66 \times 3}{2} = 34.19$ = breadth at surface of ground.

$\frac{15.2+34.19}{2} = 24.69$ feet for the mean breadth of the mean transverse section.

$24.69 \times 12.66 = 312.57$ square feet for the area.

$312.57 \times 478.5 = 149564.74$ cubic feet.

49854.9

5539.4 cubic yards, for the content of the solid between V W and head of Canal; profile A C.

2

EXCAVATIONS.

1. ROCK.

Plan Z, No. 3.—Profile A C.

2

1. From the head of the Canal at A to B, where the line of low water level intersects with the rock. 2

1. Below the line of low water level from A to B.

2

1023 — 114.8 = 908.2 feet distance.
5. feet = least depth of water in Canal.
1. foot allowed for obstructions, &c.
0.35 = half the descent nearly, at B.

6.35 feet = mean depth below the low water level.
12.2 = breadth of the Canal from A to B.

2

12.2×6.35 = 77.47 square feet = area of the transverse section.
77.47×908.2 = 70347.24 cubic feet

From N to I = 114.8 feet, (nearly.)

5+1 = 6 feet depth of water at B N.
0.72 = descent at N.

6.72
6.72= whole depth of canal below the line of low water level at B N.

1. Breadth of canal, at B N, = 12.2 feet.
2. Breadth of canal, at S I, where the rock terminates, = 20.25 feet.

The solid, of which B N I is a section, consists of a triangular and rectangular pyramid.

12.2 × 6.72 = 81.984 square feet; area of the base of the rectangular pyramid.

$\frac{81.984 \times 114.8}{3}$ = 3137.25 cubic feet for its contents.

$\frac{114.8 \times 20.25}{2}$ = 1162 square feet for the area of the base of the triangular pyramid.

$\frac{1162 \times 6.72}{3}$ = 2603.66 cubic feet for its contents.

2603.66
3137.25

5740.91 cubic feet = the whole quantity of rock between B N and I.

2. Above the line of low water level.

A V B Z—Profile A C.
2 2

Considering the solid of which V Z B is the section, as half of a rectangular prism,

A B = 908.8 feet
2

chs. chs. chs.
Z B=7.5—1.74=5.76=380.16 feet, or 380.2 feet nearly.

V Z=10 feet = the mean depth of the rock from its surface to the line of low water level.

$908.8 - \frac{380.2}{2} = 713.7$ feet = length of the whole solid.

713.7×12.2×10=87051.4 cubic feet.

3d. For the foundations of canal walls, viz: from I to V, (prof. A C)
2

Distance = B V+B I=520 feet—*(assumed.)*
Average breadth = 5.16 feet.
Average depth = 6. feet.

$\frac{5.16\times6\times520}{2} = 1609.92$ cubic feet for each side.

3219.84 cubic feet for both foundations.

Recapitulation of the Rock to be excavated.

			Cubic feet.
1. Below the level of low water from head of canal to B			70347.24
2. From N to I - - - - - - - - -			5740.91
3. Above the level of low water:			
1. From A to B - - - - -	87051.4		
2			
2. From I to V, for foundations - -	3219.84		
	90271.24	90271.24	
			166359.39

166359.39 cubic feet

55453.13

6161.4 cubic yards

Masonry of the Canal.

1. From the end of the canal, at the last water shop, to H I.
Distance = 2145 feet.

Feet.

14.7 = mean depth of earth from surface of the ground to level of low water.

0.48 = half the descent from end of rock at I, to end of canal.

0.72 = whole descent from head of canal to I.

5.0 = least depth of water in canal, from I to the last water shop.

20.90 feet = mean height of the walls above the foundations.

$\frac{20.90}{4}$ = 5.2 nearly = mean thickness of walls.

20.9 × 5.2 = 108.68 square feet = area of mean section of the walls above foundations.

$5.2 + \frac{5.2}{4} + 1.50 = 8$ feet, breadth of the foundations.

8 × 3 = 24 square feet = area of their mean sections; and

108.68 + 24 = 132.68 square feet, which is the area of the mean transverse section of the whole wall, including the foundation.

$2145 \times 132.68 = \frac{284598.6}{2}$ cubic feet for each side wall.

and 569197.20 cubic feet, in both side walls of the canal.

End Wall of the Canal.

The height of the surface of the ground at the lower [end] of the canal is only 12.1 feet above the level of low water; but the rise of the river above the dam, and, consequently, the height of the water in the canal, will exceed that amount; the height of the end wall will, therefore, be taken at the mean height from I, to end of canal.

The dimensions and area of its transverse section will also be the same, viz: = 132.68 square feet, including the foundation.

The length of this wall is equal to the breadth of the canal at bottom, added to twice the thickness of the wall, at its base, added to the base of its talus, nearly, omitting to compute the small solids formed by the talus at the angles; and, also, the projection of the foundation at the outside of the corners

$20.25 + \overline{6.5 \times 2} + 26 = 35.85$ feet the whole length of the wall.

35.85 × 132.68 = 4756.578 cubic feet for its content.

569197.2
4756.57

573953.77 cubic feet of masonry. from H I to end of canal, including the end wall.

From this amount must be deducted for four forebays, which it includes, viz:

3 forehays, 8 feet wide at bottom,
1 forebay, 4 feet wide at bottom.

The base to the talus of the walls of these forebays, is one-eighth the altitude.

The mean width at their entrances, or junction with the canal, is 10.6 feet for the forebays that are eight feet wide at bottom, and 6.6 for the one that is four feet at bottom; which are the lengths of the solids to be deducted for the respective forebays.

The area of the transverse section of the side walls, including the foundation, is 132.68 square feet.

132.68 × 10.6 × 3 = 4219.224
132.68 × 6.6 = 875.668

5094.892 cubic feet.

573953.77
5094.892

568858.878 cubic feet, or
22984.197 perches.

2. From H I to B D prof. A. C.
2

From the centre of the canal at B or N to its centre at S or I, measured on a horizontal plane, the distance is 114.84—the length of the wall connecting the corresponding points at the sides of the canal, will be taken at 115. feet, as sufficiently near, without computing it.

1. *Section at* H I.

Feet.
18. = depth of earth from the surface at I to low water level.
0.72 = descent from head of canal to I.
5.0 = least depth of water in canal at I.

23.72 = whole height of the wall at H I.

$\frac{23.72}{4}$ = 5.93 = mean thickness of wall.

23.72 × 5.93 = 140.65 sq. feet for the area of its transverse section.

2. *Section at* B D.

17.5 feet = depth, from surface of ground to the rock at D B.

$\frac{17.5}{4}$ = 4.375 feet = mean thickness of wall.

4.375 × 17.5 = 76.56 square feet = area of its section.

$\frac{140.66+76.56}{2}$ = 108.6 sq. feet = the area of the mean transverse section betwen H I and B D.

115 feet = length of each wall, $115 \times 2 = 230$; and

$230 \times 108.6 = 24978.$ cubic feet, the contents of both walls nearly between H I & B D.

4. *From* B D *to* V W.

These walls will be three feet high at V W, and will extend horizontally to their junction with the walls at B D; the area of the transverse section at V W will be $3 \times 2.5 = 7.5$ square feet nearly.

At B D the height will be 13 feet nearly, and the area of the transverse section $13 \times 5 = 65$ square feet nearly, having near 5 feet depth of superincumbent earth to sustain.

$\frac{7.5+65}{2}$ = 36.75 square feet for the area of the mean transverse section of each side wall, between B D and V W.

From B D to V W. the distance at the *side of the* canal is 381 feet nearly, $2 \times 36.75 \times 381 = 28003.5$ cubic feet contained in the two walls between B D and V W. therefore

24978. + 28003·5 = 52981.5 cubic feet or 2140.6 perches, for the contents of the two walls, from H I to V W.

Flagging at bottom of Canal.

In order to preserve the bottom of the canal from the effects of the current, it will be necessary to flag or cover it 6 inches deep with rough stone, from I, at the termination of the rock, to the end of the canal E; the distance = 2145 feet.

Breadth of canal at bottom, exclusive of the projections of the foundations, viz: 20.25—3 = 17.25

$2145 \times 17.25 = 37.001.25$ cubic feet,

or, 1414 perches.

In the preceding estimate of the canal at Zanesville, the side walls are continued on both sides from V to the last water shop. The reasons which require their construction from V to the limits of the armory, do not hold in an equal degree within the bounds of that establishment. From M to the end of the canal, the side opposite the line of the work shops may, without much inconvenience, be left without any wall. The velocity of the current, however, in this distance, must be reduced to one foot per second; and the quantity of earth to be removed will, therefore, be augmented.

The following estimate will show the extent of the proposed economy, and the alterations it will require in the dimensions of the canal from M to its end:

1. *Excavations of Earth.*

From M to last water shop = 910 feet with side wall next the river.

To put the expense of the masonry and excavations of earth nearly in equilibrium, the depth of the water must be increased to 7 feet, and its breadth at bottom becomes thirty-five feet, nearly. Then 13 feet = mean depth of earth from the surface of ground to low water level from M to end of canal—

0.72 = descent of canal at I.
0.55 nearly, descent from I to M.
7.0 = least depth of water in canal when free from obstructions.

21.27, Mean depth from surface of ground to bottom of canal, omitting to compute the trifling descent from M to end of canal, which is required to give a velocity of 1 foot per second to the current.

1. *Masonry.*

$\frac{21.27}{4} = 5.31$ nearly = mean thickness of the walls.

$\frac{5.31}{4} + 5.31 = 6.63$, nearly, thickness of walls at their base.

$6.63 + 1.5 = 8.13$ = thickness of foundations.
3. = depth of foundations.

$21.27 \times 5.31 = 112.94$ square feet, area of the transverse section of the wall above foundation.
$8.13 \times 3 = 24.39$ square feet, area of transverse section of foundations.

137.33 square feet, area of the transverse section of the wall, including foundation. The length of this wall is 910 feet, to which must be added the length of the end wall, equal nearly to the mean width of the canal, computing the area of its transverse section to be uniform, and equal to that of the side wall.

$\frac{21.27 \times 3}{2} + \frac{21.27}{8} + 35 = 69.56$, breadth of canal at surface of the ground.

$\frac{69.56 + 35}{2} = 52.28$ feet, the mean width of canal, and which is the mean length of end wall nearly.

$910 + 52.28 = 962.28$, whole length of wall.

$962.28 \times 137.33 = 132149.9$ cubic feet, from which must be deducted for the forebays, viz:

6 forebays, mean width = 10.66 feet nearly, each.
1 forebay, mean width = 6.6 nearly.

$6 \times 10.66 + 66 = 70.62$.

$112.94 \times 70.62 = 7975.82$ cubic feet.

132149.9
7975.82

124174.08 cubic feet required for the side wall next the river.

No deduction is made for the foundations of the side wall opposite the entrance of the forebays, because the bottom of each forebay will be near three feet above the bottom of the canal, in the present case, and will require a wall of that height for its security. The foundation of the side wall is nearly equivalent to the quantity of masonry that will be necessary for that purpose.

Excavations of Earth.

1. Area of that portion of the transverse section contained between the bottom of the canal.

$$\frac{21.27\times3}{2}+\overline{35-.75}\quad 56.15.$$

$$\frac{56.15+34.25}{2}\times21.27=961.4$$

$$\frac{21.27}{4}+8.13\times21.27=258.86$$

961.4 + 258.86 = 1220.26 square feet, the area of the mean transverse section of the solid to be excavated from M to end of canal, and

1220.26 × 910 = 1210426.60 cubic feet its content.

The excavation for the end wall will be

258.86×52.58.+2×8.13 = 17819.922 cubic feet nearly. Omitting to compute the small solids at the angles.

1210426.8
17819.22

1227245.82 cubic feet, which is the whole quantity of earth to be excavated from M to end of canal, when only one side wall is employed.

The quantity to be excavated in the same distance, with two side walls, as before calculated, is:

1069.52×910 = 973263.2 cubic feet: and
15298.8 for the end wall.
988562.0 cubic feet, from M to end of canal.

The quantity of masonry, as before calculated, for the two side walls, is:

132.68×910×2=241477.6 cubic feet for side wall;
And 4756.56 for the end wall.

246234.16
9314.136 deduct for forebays.

Leaving, 236920.024 cubic feet.

236920 cubic feet, with two side walls from M to end of canal.
124174 cubic feet, with only one side wall.

112756 cubic feet difference, or
4555.8 perches.

1227245.85 cubic feet of earth to be excavated, with one side wall,
988562.0 with both walls.

238,683.85 cubic feet difference.

79894.6

8877.1 cubic yards.

By which it appears that 4555.8 perches of masonry will be saved by constructing only one side wall from M. to end of the canal; and that an additional excavation of 8877 cubic yards of earth will be necessary. Also, a saving of

$$\frac{910 \times 19.75}{2 \times 24.75} = 363.1$$ perches of rough stone for flagging.

Site at the Falls of Beaver, near the Ohio.

16.6 feet, whole head and fall employed on the wheels: equal to 14.5 feet virtual head, acting by its gravity on two overshot, and one breast wheel.

66 cubic feet of water required per second.

Mean velocity of the current through the rock, from A to S, and from T to V, is two feet per second.

Mean velocity where the canal passes through earth, is nine inches per second.

		feet.
Descent from A to X =	7.27 inch	= 0.606 nearly
from X to N =	0.71 inch	= 0.06 nearly
from T to V =	0.	inconsiderable.
Whole descent through rock =	7.98	= .666 feet.

These velocities and descents are calculated on the hypothesis that the column of water in motion is one foot less in depth and in width than the canal. Consequently, neither the descent or velocities will be equal to what are stated above whenever the canal is free from obstruction, or is less obstructed than is here supposed. The small velocity allowed to the current where the canal passes through earth, requires a descent less than the probable errors of the instrument employed to take the levels, and is too inconsiderable at any rate to af-

fect the estimates to an extent worth notice. It may be omitted with safety in calculating the excavations of earth. And, from V to W, and on G P T, it is omitted altogether, including the descent through the rock: for the descent of the canal no longer adds to the depth of the excavation from V to the first water-shop, in consequence of the disposition of the ground, which leaves it optional to increase or diminish the cutting at pleasure.

Excavations of Canal.

1. Rock.

Plan B, No. 3—Profile A. E.

1. From A at head of canal, to X, where the level of low water at the dam intersects the surface of the rock.
Distance = 2457 feet.

	feet.
1. Average depth of rock above the level of the dam, -	15.42
2. Least depth of water in canal below the level of the dam,	3.0
3. Half the descent from A to X, - - - -	0.3
4. Add for obstructions, &c. - - - -	1.0
Mean depth of rock to be excavated - -	= 19.72

Width of canal = 12 feet.
19.72 × 12 × 2,457 = 581424.48 cubic feet.

193808.16

21534.2 cubic yards.
Averaging 19.72 feet deep.

2. From X to N where the surface of the rock intersects with the bottom of the canal = 240 feet.

	feet.
1. Least depth of water in canal at X below the level of the dam,	3.0
2. Descent at X - - - - - -	0.6
3. Add for obstructions, &c. - - - - -	1.0
Depth of rock to be excavated at X - - -	= 4.6

At S it is nothing.

The width of the bottom of the canal at S is nearly the same as its width through the rock. If, then, the inclination of the surface of the rock is supposed to be uniform from X to S, where it sinks below the bottom of the canal, the solid to be excavated will be the half of a prism, viz:

$$\frac{4.6 \times 12 \times 240}{2} = 6624 \text{ cubic feet.}$$

2208

245.3 cubic yards.

3. From T to V = 165 feet.

1. Average depth of the rock above the level of the dam	3.48	feet.
2. Least depth of water below the level of the dam	3.0	
3. Add for obstructions - - - -	1.0	
4. Whole descent, including half the decent from T to V	0.8	nearly.
Mean depth of rock to be excavated - -	= 8.28	

Width of canal 12 feet.

$8.28 \times 12 \times 165 = 16394.4$ cubic feet.

5464.8

607.2 cubic yards.
Averaging 8.28 feet deep.

The rock is averaged and taken at a uniform depth from T to V, consequently the width of the canal is also estimated to be uniform. The rock declines rapidly, however; and, it is believed, sinks below the bottom of the canal in a much less distance than is here assigned. The canal will widen as the surface of the rock is depressed, and the difference between the solid now supposed to consist of rock, and the actual quantity of it which may be excavated, will more than compensate for the increased width, and removal of the additional quantity of superincumbent earth at T and V.

Recapitulation of the rock to be excavated.

1. From A to X = 21534.2 cubic yards, 19.2 feet deep.
2. From X to N = 245.3 cubic yards, 2.3 feet deep, 6 feet of earth.
3. From T to V = 607.2 cubic yards, 8.28 feet deep.

607.2
245.3

852.5 cubic yards, averaging 8.3 feet deep at —— per yard.
21534 cubic yards, 19.72 feet deep at —— per yard.

EXCAVATIONS.

Earth.

1. From Y, where the rock first disappears from the surface, to X, where it sinks below the level of the dam, the distance is 495 feet; the mean depth of earth is less than 2½ feet. The whole solid is, therefore, too inconsiderable to require an exact calculation of the pyramids, &c. which compose it; computing from its mean depth, gives

$$12 + 3 + \frac{2.5 \times 3}{2} \times 495 \times 2.5 = 20882.8 \text{ cubic feet.}$$

6960.9

762.3 cubic yards.
Averaging 2½ feet deep.

2. From X to T, = 2475 feet.

1. Average depth of earth above the level of the dam,	= 5.75
2. Least depth of water in canal below the level of the dam,	= 5.0
3. Descent of canal at X,	0.6 nearly.
4. Half the descent from X to T,	0.1 nearly.
5. Add for obstructions,	1.0
Average depth, including the rock from X to N,	= 12.45

The mean velocity of the current is 9 inches per second; therefore,

$\frac{66}{.75}$ = 88 square feet, the area of the transverse section of the column of water.

$\frac{88}{5}$ = 17.6 feet, the mean width of the column.

$17.6 - \frac{3 \times 5}{2}$ = 10.1 feet, least width of the column of water at bottom.

$10.1 + 1$ = 11.1 feet, width of canal at bottom.

$12.45 \times 3 + 11.1 = 48.45$ feet, width of canal at the surface of the ground.

$\frac{48.45 + 11.1}{2}$ = 29.775 feet, mean width of the mean transverse section of the canal.

$29.78 \times 12.45 \times 2475 = 917905.72$ cubic feet.

305968.5

33996.5 cubic yards.

Including the rock between X and the bottom of the canal at N, which

has been calculated separately, and must, therefore, be deducted from the above amount,

33996.5
245.3 cubic yards of rock.

33751.2 cubic yards of earth,
Averaging 12.45 feet deep.

3. From V to the first water shop at W = 2390 feet.

1. Average depth of earth above the level of the water in the canal	2.0 feet.
2. Least depth of water in the canal	4.0
3. Add for obstructions	1.0
Mean depth of earth to be excavated =	7.0 feet.

$\frac{88}{4} = 22$ feet, mean width of the column of water.

$22 - \frac{4 \times 3}{2} = 16$ feet, width of the column of water at bottom.

$16 + 1 = 17$ feet, width of canal at bottom.

$17 + \frac{7 \times 3}{2} = 27.5$ feet, mean width of canal.

$27.5 \times 7 \times 2390 = 460075$ cubic feet.

153358.3

17039.8 cubic yards, averaging 7 feet deep.

From V to W the descent does not affect the excavations, and were, therefore, omitted in estimating the dimensions. From V to the first water shop, the ground admits of placing the canal nearly at will, so far as regards the cutting.

4. From W, to the last water-shop at E, is 580 feet. (Plan B, No. 3, Profile A E.)

The canal to be walled on the side next the water-shops.

1. Average depth of earth above the level of the dam,	7.05 feet.
2. Least depth of water in the canal,	4.0
3. Whole descent at W, including half the descent from W to E,	0.9 nearly.
4. Add for obstructions,	1.0
Making the average depth of canal, =	12.95 feet,

or, 13 feet, nearly, from W to E, below the surface.

$\frac{13}{4} = 3.25$ feet; mean thickness of the side wall.

$3.25 + \frac{13}{16} = 4.062$ feet; thickness of the wall at its base, or 4.1 nearly.

$4.1 + 1.2 = 5.3$ feet, breadth of the foundation of the wall; its depth is taken at 3 feet, (soil, a light loam.)

The velocity of the current is 9 inches per second; and the area of the transverse section of the column of water is therefore $\frac{66}{.75} =$ 88 square feet, as before. Then,

$\frac{88}{4} = 22$ feet, the mean width of the column:

$22 - \frac{4}{16} - \frac{3 \times 4}{4} = 18.75$ feet; least width of the column of water at bottom of canal.

$18.75 + 1 = 19.75$ feet; width of canal at bottom

$19.75 - .6 = 19.15$ feet; width of the bottom, exclusive of that part of the foundation which projects beyond the base of the side wall into the canal.

$19.15 + \frac{3 + 13}{2} = 38.65$ feet; width of canal at surface of the ground, exclusive of the talus of the wall, and projection of the foundation.

$\frac{38.65 + 19.15}{2} \times 13 = 375.7$ square feet; area of that part of the transverse section, contained between a perpendicular raised from the inner edge of the foundation to the surface of the ground; and the opposite side of the canal

$13 + 3 = 16$ feet; the depth from the surface of the ground, to the bottom of the foundation of the wall.

$\frac{16}{4} + 5.3 = 9.3$ feet; the mean width of the solid to be excavated, which includes the space occupied by the side wall and its foundation.

$9.3 \times 16 = 148.8$ square feet; area of its transverse section.

$375.7 + 148.8 = 524.5$ sq. ft. the area of the whole transverse section of earth to be excavated.

If the mean width of the solid, which includes the space to be occupied by the side wall and its foundation, be added to the distance from W to the last water-shop at E, it will include the solid to be excavated at the end of the canal on account of the end wall, (nearly,) there-

fore, 580 + 9.3 = 589.3 feet, is the whole distance to be excavated; and,
589.3 × 524.5 = 309087.85 cubic feet; or

19447.69 cubic yards:
Averaging 14 feet deep.

Masonry of the Canal.

From W to E at the end of the canal, is 580 feet; and is the length of the side wall. The length of the end wall at E is equal to the width of the canal at the surface of the ground added to the breadth of the base of the side wall (nearly.)
19.75 feet, width of the canal at bottom,
13.00 feet, average depth of the canal,

$\frac{13}{8} + \frac{3 \times 13}{2} + 19.75 = 40.87$ feet; width of canal at the surface of the ground; and
40.87 + 4.1 = 44.97 feet; length of the end wall.
580 + 44.97 = 624.97 feet; length of the two walls: from which must be deducted for four forebays: two with 13 feet, and two with 8 feet, mean width, each, viz: $\overline{13 \times 2} + \overline{8 \times 2} = 42$ feet.
624.97 — 42 = 582.97 feet; whole length of wall to be computed.
3.25 feet, mean thickness of the wall above its foundation.
13.00 feet, mean height of wall above the foundation; and
13 × 3.25 = 42.25 sq. feet; the area of its transverse section.
5.3 feet, width of the foundation.
3.0 feet, depth of the foundation.
5.3 × 3 = 15.9 square feet for the area of its transverse section.
42.25 + 15.9 = 58.15 square feet; the area of the transverse section of the whole wall, including the foundation; and
582.97 × 58.15 = 33899.7 cubic feet or,

1369.6 perches its solid content.

The Wier.

It is proposed to place a wier at M (Plan B and profile A E) 2000 feet from the dam; where the canal may approach within 80 feet of the river bank: and where the intermediate body of rock is covered with earth from two to four feet deep. The surface of the ground is here six feet; and the surface of the rock about four feet above the level of the proposed dam.

The mean width of the wier is 80 feet: its bottom to be on a level with low water at the head of the canal; and consequently several feet higher than the greatest elevation of the Beaver, at the point where the waste or surplus water of the canal will be discharged. The solid to be excavated may be considered as equal to a prism of the above

dimensions, (which it is nearly:) the inclination of the surface of the ground towards the river, differing but little from the slope of the bottom of the wier; therefore,

$80 \times 30 \times 6 = 38400$ cubic feet, or

1422.2 cubic yards, is the solid to be excavated, of which $\frac{2}{3}$ are rock: which consequently $\frac{1422.2 \times 2}{3} = 948$ cubic yards of rock, averaging four feet deep; with two feet earth on the surface, and

$\frac{1422.2}{3} = 474$ cubic yards of earth, averaging two feet deep.

The foregoing estimate for the canal at Beaver is made conformable to the levels taken on two routes, from the head of the falls, to Walnut Run, and which pass within a few feet of the same point between the mound (plan B, No. 3) and the river bank—viz: from A to T (plan B, No. 3 profile A E, No. 3.) the depths of the excavations conform strictly to the levels exhibited on the profile No. 2. Plan B, No. 2 (from T to V, the levels exhibited on the profile A E, No. 3) were adopted; and from V to W, (plan B, No. 3 profile A E, No. 3) the depths were taken less than those exhibited on profile No. 2, and greater than those on profile No. 1, the surface of the ground leaving it optional to take the canal along any line between the two. The first of these routes (profile B, No. 1) was a trial route, the other, (profile B. No. 2, was located previous to the investigation for determining the quantity of water in the Beaver during its lowest stage; and had for its principal object, to obtain a uniform cutting or depth of ground five feet above the level of the dam: under an idea that our inquiries concerning the least quantity of water which the stream afforded might result in showing the utility, if not necessity, of employing the whole fall, including the difference between the high and low water level at Walnut Run to be employed on reaction wheels, using the tail water of the breast and overshot wheels when the river should be low, and shutting off the tail water and applying the surplus water of the canal, during a freshet, or simultaneous high rise of the Beaver and Ohio.

It has been subsequently ascertained that there is no necessity for resorting to this power at all; and no advantage to be derived from the extensive use of it for the purposes of the armory now contemplated.

There is no longer any reason to prefer taking the canal through the ground much higher than the dam.

From G plan B, No. 2 profile No. 2, to the mound at C, where all these routes are made to pass, and to intersect or approach near each other, the surface of the ground is an inclined plane, descending towards the river bank; and admits of taking the canal from G to T

with the same depth of cutting, it is believed, as from V to W. The route No. 1, passes obliquely over this plane; and the profiles No. 1 and 2 exhibit the character of its surface with sufficient exactness to show that the excavations may be diminished so as not to exceed an average of two feet of earth above the level of the water in the canal.

The descent therefore will not affect the depth of the excavations, and will not be considered in the estimate.

The distance from G to T. is 90 poles, or 1485 feet on the route which has been estimated. The proposed route G P T. between those two points, will probably increase the distance to 95 poles, or 1568 feet nearly. From G. at the commencement of both routes, the first 10 poles on either side will not afford any material difference in the depth of ground: the distances therefore to be compared, are 80 poles or 1320 feet on the old route, and 85 poles or 1403 feet nearly on G P T.

1. The average depth of ground above the level of the water in the canal, will be taken at 2 feet: the dimensions and area of the canal will therefore be the same as from V. to W. viz:

$27.5 \times 7 = 192.5$ square feet for the area of the mean transverse section.

$192.5 \times 1403 = 270077.5$ cubic feet,

90025.83

10002.8 cubic yards to be excavated on the proposed route G P T, averaging 7 feet deep.

The area of the mean transverse section of the canal, on the old route between G and T, as before calculated, is 370.871 square feet: the average depth of the bottom of the canal is 12.45 feet. Therefore,

$370.871 \times 1320 = 489549.72$ cubic feet

163183.24

18131.47 cubic yards, averaging 1245 feet deep on the route located from G to T, and included in the preceding estimates.

	Cubic yards.
The whole quantity to be excavated from X to T is	= 33751.2
Deduct from G. to T, as above - - - - -	18131.4
Leaves -	15619.8
	Yards
Averaging 12.45 feet deep: and - - - - -	10002.8

on the route G P T, averaging 7 feet deep; or a difference in favor of the proposed alteration of 8128.6 cubic yards, averaging 12.45 feet deep: and more than 5 feet difference in the depth of excavating 10002 yards.

It is also probable that the canal may be taken out several perches lower down the stream without any disadvantage. The reason for

placing it in its present position, was, in order to be certain of having sufficient room to build the dam at a proper distance above the falls.

RECAPITULATION-

1. EXCAVATIONS OF EARTH.

1. From Y. to X.	762.3	cub. yds.	averaging	2½ feet deep.
2. From X. to T.	15,619.8	do.	do.	12.4 ft. (old route.)
	10,002.2	do.	do.	7. ft. dp. on G.P.T.
3. From V. to W.	17,039.8	do.	do.	7. feet deep.
4. From W. to E.	19,447.69	do.	do.	14. feet deep.
5. Wier at M.	474.	do.	do.	2. feet deep.

2. ROCK.

1. From A. to X.	21,534.	cub. yds.	averaging	19.72 feet deep.
2. From X. to N.	245.3	do.	do.	4.6 feet deep under 7 feet of earth.
3. From T. to V.	607.2	do.	do.	8.28 feet deep.
4. Wier at M.	948.	do.	do.	4. feet deep.
Total,	23,334.5	cubic yards.		

3. MASONRY.

1369. Perches.

Site at the Ohiopyle Falls of Youghiogeny River.

The fall at this site is greater than what is necessary; and a canal that would suffice to convey the requisite quantity of water during the driest season, for a head of 50 or 60 feet, on two successive sets of wheels, might be too small to preserve the greater part from being frozen during the winter. Its dimensions must therefore be regulated almost exclusively with a view to obviate obstructions or inconvenience which may arise from this cause. It is believed that running water seldom or never freezes deeper than a foot in this climate. Whenever it acquires greater thickness, it is most probably in consequence of accumulation on the surface, and not from its formation at the under side. If, then, the canal is made five feet deep below the level of the dam, and four feet wide at bottom, the space occupied by ice, one foot thick at the surface and six inches at the sides, would still leave an area of 36 square feet to the transverse section, which would admit the passage of a sufficient column of water with a mean velocity of only nine inches per second, to supply a head of 39 feet acting by its gravity.

EXCAVATIONS.

1. *Earth.*

PLAN O.—PROFILE A D.

1. From A, at the head of canal, to where the rock is supposed to begin at R, 1,229 feet.

1. Average depth of earth from surface of ground to low water level - - - - - - = 8.0 *feet.*
2. Depth of water in canal - - - - - 5.0

Mean depth of excavation - - - = 13.0

$\frac{13 \times 3 + \overline{2 \times 4}}{2}$ = 23.5 feet mean width of canal.

23.5 × 13 × 1,229 = 375,459.5 cubic feet.

125,153.1

13,905.9 cubic yards, averaging 13 ft. deep.

2d. From R to end of canal at B, where the basin or penstock will be placed = 878 feet, (nearly.)

It is assumed, that the rock is only four feet below the surface of the ground along the whole of this line, which is a more unfavorable supposition than the appearance of the ground and the trees growing on it would warrant.

Width of canal through the rock - - = 12 feet,
Two berms at the base of the earth slopes 1.5 feet each = 3 feet.

Making 15 feet

width of earth to be excavated at the surface of the rock.

4 × 3 + 15 = 27 feet width of canal at surface of the ground.

$\frac{27 + 15}{2}$ = 21 feet, mean width of excavation

21 × 4 × 878 = 73,752 cubic feet, or

24,450.6

2,716.7 cubic yards, averaging four feet deep.

2. *Rock.*

From R to B = 878 feet.
Average depth of rock above the level of the dam, = 11.47
Least depth of water in canal - - - = 3.
Add for ice, &c. - - - - = 1.

Mean depth of rock to be excavated - - = 15.47 feet.
Width of canal - - - - - 12 feet.
12 × 15.47 × 878 = 163,869.9 cubic feet.

54,623.3

6,069.2 cubic yards.
Averaging 15.47 feet under four feet of superincumbent earth.

RECAPITULATION.

1*st.* *Excavations of Earth.*

1. From A to R, 13,905 cubic yards, averaging 13 feet deep.
2. From R to B, 2,716 cubic yards, averaging 4 feet deep.

2*d.* *Excavations of Rock.*

6,069.2 cubic yards rock, (sand stone,) averaging 15.47 ft. deep.

Site below Putnam, on the Muskingum River.

17.1 feet fall, from surface of a 7 foot dam to end of canal.
13 feet head on the wheels.
150 cubic feet water required.
12 inches per second velocity of the water in canal when it passes through earth.

EXCAVATIONS OF THE CANAL.

Earth.

Plan P. Profile A F and F I.

1. From A to B = 996.6 feet.

1. Height of surface of the ground above the level of the dam, on the line A B - - = 8.533
2. Least depth of water in the canal - - = 7.75

Making the breadth of the bottom of the canal equal to the whole depth of water contained in it at the lowest stage, will give very nearly a section of the least expensive excavation. The expression of the area of that part of the canal below the level of the low water at the dam becomes——

$\frac{3a+2a}{2} \times a = 150$, where $a =$ the depth.

$5a^2 = 300$, & $a = \sqrt{\frac{300}{5}} = 7.7459 = 7.75$ nearly for the depth of the canal below the level of the dam and its breadth at bottom.

Thus 8.53 + 7.75 = 16.28 for the whole depth of the excavation.

7.75
16.28

16.28 × 3 + 7.75 = 56.59 feet for the breadth of the excavation at the surface of the ground.

3
48.84
7.75
56.59

and $\frac{56.59+7.75}{2} = 32.32$ feet for the mean breadth of the section of the canal. Consequently,

32.32 × 16.28 × 996.6 = 524371. cubic feet, = 19.421 cubic yards, averaging 16 feet deep.

32.32
32.56
4884
3256
4884
526.16.96
996.6
315696
315696
473544
473544
3)524371.056
9)174790.35
19421.15

2. From C to D = 957 feet.

1. Average height of surface of ground above the level of the dam - - } = 2.617 feet.

There, the small elevation of the ground, above the low water level in the canal, will not influence its dimensions. The least depth of water will be taken at four feet, which determines the breadths and whole depth of excavation, viz:

$\frac{150}{4} = 37.5$ = the mean breadth of the section occupied by the water.

$37.5 - \frac{3 \times 4}{2} = 31.5$ for the breadth of canal at bottom.

$31.50 + \overline{3 \times 4 + 2.617} = 51.351$ feet for the breadth of the canal, at the surface of the ground.
4.

6.617
3
19.851
31.5
51.351

And $\frac{51.351 + 3.15}{2} = 41.42$ feet for the mean breadth of the excavation.

2.617+4=6.61 feet for the depth; consequently,

6.61×41.42×957=262007 cubic feet, or 9815 cubic yards,
6.61 with 6.61 feet average depth.

4192
24852
24852
273.7862
957
191646
136890
246402
3)262007.46
9) 87335·8
9815.

Excavations of Canal.

ROCK.

From E to X=620.40 feet.

Average height of the rock above the level of the dam = 7.9 feet. The velocity of the current, in this distance, may be increased at pleasure. The dimensions of the excavation will, therefore, be taken at the adopted minimum, for such cases, as it regards the expense, viz:

12 feet breadth of the canal.
4 feet least depth of water.

Then, 7.9+4=11.9 feet, whole depth of excavation, and
11.9×12×620.4=88593.12 cubic feet = 3281 cubic yards, at an average depth, below the surface of the ground, of 7.9+16.253=24.15 feet.

12	142.8
142.8	49632
	12408
	24816
	6204
	3) 88593.12
	9) 29531.04
	3281.2

The velocity through the rock, in this case, becomes

$$\frac{150}{48} = 3.125 \text{ feet per second.}$$

Excavations of Earth.

From E to X = 620.4 feet.

1. Average depth of earth from surface of the ground to the rock, = 16.253 feet.
Average breadth of canal through the rock, = 12. feet.
Add for the breadth of the two berms, = 3. feet.

Average breadth of the excavavation at the top of the rock = 15 feet.

16.25×3+15 = 63.75 feet for the breadth of the excavation at surface of the ground.
3.

48.75
15.

63.75

And $\frac{63.75+15}{2} = 39.375$ feet for the mean breadth of the mean section.

$39.375 \times 16.25 = 639.84$ for its area.

$639.84 \times 620.4 = 396956$ cubic feet, or 14,702 cubic yards; having an average depth of 16.25 feet.

62.04

2558 36
127968
383904

3) 396956.736

9) 132318.9

14702.

From X to H = 4,191 feet.

1. Average depth of earth above the level of the dam, 20.4 feet. Here the breadth of the canal at bottom may be taken at its minimum, viz: one-half the depth of the column of water below the level of the dam; and the expression of the area of the section below that level, becomes $\frac{4a^2}{2} = 150$, and $a = \sqrt{\frac{300}{4}} = \sqrt{75} = 8.66$ feet nearly, when a is taken equal to the depth.

And $8.66 + 20.4 = 29.06$ feet, for the whole depth of the excavation.

$29.06 \times 3 + \frac{8.66}{2} = 91.5.1$ feet for the breadth of excavation at the surface of the ground: therefore,

87.18
4.33

91.51

$\frac{91.51 + 4.33}{2} = 47.92$ feet for the mean breadth of the mean section of the canal, from X to H.

Therefore, $47.92 \times 29 \times 4,085 = 5,676,842.8$ cubic feet.

1,892.280.9

210,253.4 cubic yards.

1. The dimensions and area of that portion of the transverse section of the ground to be excavated, which is contained between a perpendicular raised from the inner edge of the foundation of the wall, and the opposite side of the canal, are as follows?

18.15 feet = depth of earth above the level of the dam.
10.68 feet = depth below the level of the dam to the bottom of the canal.
28.83 feet = whole depth of ground to be excavated.

$\frac{28.83 \times 3}{2} + 5.34 = 48.585$ breadth at surface of the ground.

$\frac{48.585 + 5.34}{2} = 26.962$, the mean breadth.

$26.962 \times 28.83 = 777.31$ square feet for the area.

2. Dimensions and area of that portion of the transverse section of the earth to be excavated which is contained between the perpendicular and the bank next the river, viz:

Depth of earth from the surface of the ground to the bottom of the canal	= 28.83
Depth of foundation of the wall	3. 5
Total depth	= 32.33
Breadth of foundation	= 8.775

From H to I, at end of canal, 586 feet.

1. Average depth of earth above the level of the dam, 18.15 feet.

The canal from H to I will be walled, as in other cases, on the side next the river. The base of the earth slope, opposite the wall, continues the same as before, viz: one and a half times its altitude; the base of the talus to the wall is one eighth its altitude; the breadth of the canal at bottom is half the depth of the column of water at a low stage of the river. The velocity of the water is one foot per second. The quantity to be conveyed 150 cubic feet per second

Hence, $\frac{5a}{2} + \frac{a}{8} \times a = 150 \times 2 = 300$; where a is taken equal to the depth; and $a2 = \frac{300 \times 16}{42} = 114.3$ feet nearly.

and $a = \sqrt{114.3} = 10.68$ nearly.

The highest rise of the river above the dam, is	= 11 feet
The depth of water in canal, as found above, is	= 10.68
The greatest depth of water in canal, which is also the height of the side wall	= 21.68

$\frac{21.68}{4} = 5.42$ feet = the mean thickness of the wall.

1.355 feet = half the talus.

6.775 feet = thickness of the wall at its base.
2.00 feet = extension of the foundation beyond the base.

8.775 = thickness of the foundation.
and 3.5 feet = the depth of the foundation.

From H to I = 586 feet.

A base to the slope of the earth bank, which will barely retain it in its position during the erection of the wall, is all that is necessary; half the altitude is sufficient for that purpose: therefore,

$\frac{32.33}{2} + 8.775 = 24.940$ feet breadth at top.

$\frac{24.94 + 8.775}{2} = 16.857$ feet for the mean breadth.

$16.857 \times 32.33 = 544.98$ square feet for the area.

$723.39 + 544.98 = 1{,}268.37$ square feet for the area of the whole transverse section,

and $1{,}268.37 \times 586 = 743{,}264.82$ cubic feet.

247,754.94

27,528.32 cubic yards.

Omitting to estimate the prism and pyramids at the end as of comparative small value, and unnecessary for the occasion.

Excavations.

RECAPITULATION.

1. Averaging 6.61 feet deep, at 10 cents per cubic yard.
From C to D, = 9815 at 10 cents, = 981.5

2. Averaging 16.25 feet at
1. From A to B, 19421. cubic yards.
2. From E to X, 14702.

34123 cubic yards at

3. Averaging 30 feet deep.
1. From X to H, 210253.4
2. From H to I, 27528.3

237781.7

9815
34123
237781

Total 281719 cubic yards.

Side or river wall from D to E, 35 feet high, mean thickness 10 feet, length 1254 feet, contents = 12666.66 perches.

Masonry of the Canal.

1. Side wall from H to I, = 586 feet.

The end wall may be taken equal in length to the mean breadth of the transverse section of the canal below the level of high water, added to the breadth of the side wall at its foundation, viz:

$$\frac{21.68 \times 8}{2} + 6.775 = 39.295$$

586 + 39.295 = 615.29 feet for the whole length of the wall; the mean thickness of which is 5.42 feet, and height 21.68 feet.

615.29 × 5.42 × 21.68 = 72299.98 cubic feet.

The foundations are 8.775 feet broad, and 3.5 feet deep.

8.775 × 3.5 × 615.29 = 18897.09 cubic feet.

72299.98
18897.09

Total 91197.07 cubic feet.

3680 cubic perches.

NOTICES OF SEVERAL SITES EXAMINED.

Stonefort, at the forks of Duck river, Tennessee.

Our return route from Alabama, passed near to this place, and was the occasion of its being visited. It is more remarkable on account of its singular military antiquities, than the advantages of its position for an Armory. It is perhaps the only instance among the remains of ancient fortification, in this country, that discovers any evidence of the agency of water having been artificially employed and combined with other means of permanent defence.

The local situation of the ground is favorable, and the water from both forks of the river, might be employed at one point, with perfect security to the works. The fall was estimated at sixty feet or more, in the distance of a mile; and although the quantity of water furnished by the two streams, during a dry season, could not be ascertained, it is probable that they would afford sufficient power.

Its distance from navigation, and the limited resources of the country around it, render a more particular description of the site unnecessary.

The nearest point from whence boats descend the river, is said to be at Shelbyville, twenty miles below, and even from Columbia the navigation is only occasional, and attended with too much uncertainty to be relied on for the purposes of an Armory. Supplies would arrive by the way of Nashville, and be transported a distance of sixty-five miles by land.

The falls of Caney Fork of the Cumberland, are about fifty-two miles by land, above the junction of the two rivers, and fifty-three from Carthage. They consist of two principal falls, about one hundred and fifty yards apart, and a rapid of considerable descent, at the foot of the lower fall. The power which they afford at the stage of water, when it was examined, is among the greatest we have met with. The whole fall cannot be less than sixty or eighty feet, but there is no site for an extensive establishment, and the position does not afford sufficient space for the necessary buildings without ascending to the summit of the hills.

From the upper to the lower fall, and below the foot of the last rapid, extending as far as could be observed, the right bank of the river consists of high limestone cliffs, occasionally overhanging their base. A high and steep hill side occupies the intervening distance between the lower fall and foot of the lower rapid, and barely affords sufficient room to place the water shops.

The left bank of the river is even more unfavorable. Keel boats occasionally ascend the Caney Fork to Allen's Ferry, supposed to be twelve or fifteen miles below the falls, and might, it is said, proceed to the foot of the rapid, during the greatest part of the year; however, the communication would probably be by land to Carthage, on the Cumberland river, one mile below the mouth of Caney Fork.

Falls of Fallingwater, a branch of the Caney Fork of Cumberland.

These falls are four miles above the mouth of Fallingwater, and thirty-seven miles by land from Carthage, on the Cumberland river. The whole descent is probably more than one hundred and fifty feet in less than half a mile. One cascade alone is sixty or eighty feet high.

The Fallingwater is of the smallest class of mill streams, on which it would be prudent, under any circumstances, to establish an Armory. It is liable to be reduced so low, as to render the extensive employment of its water power greatly inconvenient, and nearly impracticable. According to the best information we could obtain, it is probable that the quantity of water which it furnishes, has, at times, been less than eight cubic feet per second. It would, therefore, require to be used on a number of wheels in succession, and those of the largest dimensions; four at least would be indispensable, and each, from thirty to forty feet in diameter. The ground, however, does not admit of this arrangement, without an expense altogether disproportioned to

the advantages of the site. Below the falls, the stream is bounded on both sides by steep hills and high precipices, which continue about two miles, before ground, sufficiently low, can be obtained to apply the water as often as might be necessary; and it is doubtful if an open canal could be taken half of that distance, in consequence of high intervening ridges, which terminate abruptly at the water edge of the stream.

The west fork of Red river, near Clarksville, Tennessee, Fountainville powder works, on Lynn Camp, and Falls of Rough creek, branches of Green river, Otter creek, and Doe Run, emptying into the Ohio below Louisville, Fourteen Mile creek, in Indiana, Elk Horn, a branch of the Kentucky river, were severally examined, and found to be deficient of water during dry seasons, and, in some instances, liable to be interrupted by freshets. Doe Run is a diminutive but remarkably fine mill stream. It has a great fall, fluctuates but little in its volume of water, has the advantage of being near the Ohio river, and its power might be sufficient, if the whole fall could be employed at one point. But there is no convenient site below the village of Little Fork, and not sufficient fall above or near to it, nor could the water be taken further down than that place without tunnelling, or resorting to aqueducts to convey it round the cliffs immediately bordering the stream. The falls of Sinking creek, nine or ten feet, were not examined; they are near its mouth, and subject to interruption from the backwater of the Ohio.

Big Blue River, in Indiana,

Empties into the Ohio about forty miles below Louisville, a mile and a half above the town of Leavensworth, and has an excellent harbor at its mouth.

Two sites were examined on this stream, but neither of them were found to possess sufficient power. The upper site affords the greatest; it has 13.32 feet fall at low water; the highest rise of any freshet is stated to be 16 feet. The lower site has only $7\frac{1}{2}$ feet fall.

The mills of Mr. Leavenworth afford a tolerable measure of the quantity of water which the river furnishes at its extreme low stage. They are twelve miles above the upper site. The proprietor states, that during two or three months in 1821, the supply of water at that point was not sufficient to enable one pair of four feet stones to perform their usual grinding. The head and fall employed at the wheels was not recollected, but the dam is nine and a half feet high. Now, taking the head only at eight feet, and applied on an undershot wheel, the quantity of water could not exceed eighteen cubic feet per second. Between these mills and the upper site, the river receives an accession nearly or quite equal to its whole volume, from the Big Fish Spring.

Hence, the whole volume supplied by the river at the upper site was probably less than thirty-six cubic feet per second. A dam fifteen feet high, at this site, would increase the fall to twenty-eight and one-third feet at low water; and, supposing all that portion of it which would not be liable to interruption by the highest rise of the river, viz: Twelve and one-third feet to be employed with overshot wheels, and the remaining part of the fall to be applied on reaction wheels, viz: sixteen feet during a low stage of water, and an equivalent power at all other times, (which is practicable) then the whole virtual head employed on the wheels would be nineteen feet nearly, (omitting to make any allowance for the descents of the canal, races, &c. or to free the wheels) and the whole quantity of water requisite for an armory would be fifty-four cubic feet per second nearly, leaving a deficiency of eighteen cubic feet per second, equal to one half the volume of the stream, with a virtual head of nineteen feet, to be remedied by increasing the height of the dam, which would not only be objectional on account of the hazard and expense, but nearly impracticable, from the circumstances of the ground.

Licking River in Kentucky,

Empties into the Ohio opposite Cincinnati; and possesses, in a high degree, many of the characteristic features and habits of the western rivers. It is long, passes through a narrow valley, and is subject to great extremes in its stages of elevation and depression. During several months, it is navigable as high as Falmouth, where it forks, forty or fifty miles from the Ohio; and in the Spring of the year, boats descend from a much greater distance. Near its mouth are several ripples at low water: the most considerable are three mile and six mile ripples, so called from their respective distances from the Ohio river. Our attention was drawn to these ripples by the favorable representations made to us of the water power they were said to afford. But judging from their appearance, in connection with the reputed character of the river, and the probability of frequent interruptions by the back water of the Ohio, we were impressed with the belief, that an adequate power could not be obtained at either of those places. The obvious advantages, however, of a position in the immediate neighborhood of Cincinnati; and also the circumstance, that many of the most respectable inhabitants of that part of the country entertained opinions decidedly different from those we had been able to form on a cursory examination, induced us to direct such levellings and surveys as might satisfy us of the propriety of going into a more minute investigation of those sites; or show the inutility of paying any further attention to them. The following abstract of the levellings, it is believed, will render any additional remarks concerning those sites altogether unnecessary. It is proper to state, however, that the bed of the Licking is limestone, and could

hardly be more favorable to the security of any dam, it might be deemed necessary or adviseable to erect on it.

The river was meandered from its mouth and levels taken for several miles above the ripples in question, and it appears that at Three Mile ripple, the whole descent in two miles and three quarters, is five feet four inches: the foot of the ripple is three feet above low water mark of the Ohio. The descent at Six Mile ripple is nine feet five and a half inches, and occurs in the distance of sixty-seven chains: the foot of this ripple is eight feet four inches above the low water of the Ohio. From the head of Six Mile ripple to the head of Deadman's ripple, is four miles; and the descent in that distance is nine feet seven and a half inches; the foot of this ripple, therefore, is seventeen feet nine and a half inches, above the level of low water in the Ohio. So, that the entire fall in eleven miles, including all these sites, from the head of Deadman's ripple to the Ohio river, and during a stage of low water in both rivers, is twenty-seven feet five inches.

The highest rise of the Ohio at the mouth of Licking, that has been correctly ascertained, is forty-seven feet.

The highest rise of the Licking at these points, independent of any rise in the Ohio, is not known. Twelve miles higher up it was measured, and found to be thirty feet.

Levels were taken at a fourth site, on the left bank of the river, twenty four miles above its junction with the Ohio. The whole fall is fourteen feet five and a half inches in three miles, thirteen chains, beginning at the mouth of Cruiser's creek and terminating near Bowman's creek. The highest rise of the river at this place is not known.

A water mark near the mouth of Cruiser's creek was found to be thirty feet above low water; and from this circumstance, it is inferred, that the greatest rise below the rapids cannot be much less than forty feet, and may exceed that height.

The greatest elevation of the Ohio river at the mouth of Licking, is within one foot of the level of Cruiser's creek, and more than thirteen feet above low water at the foot of the rapids.

The ground between the two creeks, near their junction with the Licking, is high river bottom and nearly level, the average elevation of its surface above low water at Cruiser's creek, exceeds thirty-one feet. The course of the canal would pass 3261 yards through this bottom to the nearest part of the valley of Bowman's Creek, where the water might be applied with most safety to the works, and with equal if not greater economy than on Licking river.

We did not examine this site; the foregoing facts, exhibited in the returns of the surveyor, rendered our inspection of it unnecessary. Its position offers no compensating advantages for the excessive expense that would evidently attend the occupation of it for an armory.

To aid in forming an idea of the probable cost, an estimate has been made, on the hypothesis that the dam is to be built fifteen feet high, and the works to be placed on the banks of Bowman's creek, at the point nearest to the head of the falls, where eight feet may be

employed on reaction wheels; this is done, however, for the sake of greater accuracy in the calculations, as the surveys, and levellings, furnish sufficient data for an estimate at that point only; for, if a head of eight feet with reaction wheels, would suffice at low water, it might be unnecessary to take the canal across the river bottom, and the works might be established to greater advantage, (as regards the expense.) immediately on the banks of Licking, and nearer to the dam. But we have no correct information concerning the quantity of water in the river, during its lowest stage; and, such as could be procured, does not warrant the supposition that the minimum quantity would be 258 cubic feet per second, which is the quantity required for a head of eight feet on reaction wheels. The works, therefore, would not be placed, either at the point we have assumed, nor on the Licking river, but near the mouth of Bowman's creek, where a fall of sixteen or twenty feet may be employed. The heighth of the dam, however, would not be affected by changing the location of the works, and could not be lessened without augmenting the excavations to a degree that would increase the aggregate expense.

Estimate of the expense of locating the Armory on Bowman's creek, 3261 yards from the dam on Licking river, near the mouth of Cruiser's creek.

Excavations of earth for forebays, races, and wall, in line of shops, and foundations, 15578.88 cubic yards, four to eight and a half feet deep - - - -	$ 1,620	44
For Canal.		
487,059 cub. yards, 28 feet deep, at 28 cts. per cub. yard	136,376	52
12,405 cubic yards, eleven feet deep at fifteen cents	1,860	87
For Masonry.		
Walls for forebays, races, and wall next the creek, 11,596.29 perches, at $ 2 per perch - - -	23,192	58
For arches 189$\frac{59}{100}$ perches, at $ 4 per perch - -	758	36
Canal wall at the shops, 3709.23 perches, at two dollars per perch - - - - - - - -	7,418	46
Head gate of canal near the dam feet high, including its wall and fixtures - - - - -	965	00
Two bridges over the canal at $100 each - - -	200	00
Four do over the forebays, at $ 25 each - -	100	00
Dam, 15 feet high, 530 feet long, stones of large dimensions, hammer dressed, and covered - - -	30,367	32

61 buildings, including quarters for officers, and workmen, workshops, with fixtures for the machinery, &c. see table marked - - - - - -	137,556 10
Machinery, tools, patterns, &c. - - - - -	14,522 00
Miscellaneous articles - - - - - -	1,549 00
Whole cost of labor, materials, machinery, tools, &c.	$356,486 65
Add for contingencies ten per cent. - - - -	35,648 66
For 640 acres of land, and water right, at $10 per acre	6,400 00
Aggregate	$398,535 31

The detail of dimensions of the buildings, &c. will be found in table marked——, and of the canal from page 75 to page 80 of the calculations, &c. accompanying the report.

By taking the canal half a mile farther towards the mouth of Bowman's creek, sixteen feet fall might be employed on the wheels, which would have the effect to diminish the excavations of the canal, notwithstanding the increase of its length. But the quantity of masonry would be augmented more than one half, in consequence of increasing their height by the difference of the fall, (eight feet,) supposing the existence of no other cause, for enlarging their dimensions.

Whatever difference might be produced, therefore, in the distribution of the expense, by placing the works nearer to the mouth of Bowman's creek, and employing a greater head of water on the wheels, the whole amount could not fall any thing short of the above estimate. Further, by examining the calculations, page 76, it will be seen that the dimensions of the canal are, in fact, taken at less than what would be admissible in practice. Its width, at bottom, is only equal to half the least depth of water which it holds, and no allowance is made for obstructions. It is also to be remarked, that the prices of labor, and materials, in the preceding estimate, are according to the Cincinnati rates; that the Licking is not navigable half the year, and that the distance by land from the Ohio, is twenty-five miles. The maps marked T, and numbered from 1 to 6, exhibits these several sites, with profiles of the ground through which the canals would be taken. No. 1 is a general map, embracing and connecting the whole. No. 6 contains the profiles of the ground along the route of the canal, between Cruiser's, and Bowman's creek, with sections of the canal.

Great Kenawha, Virginia.

The falls are ninety-four miles above its confluence with the Ohio; thirty-five miles, by water, above the town of Charleston, and a mile and a half below the mouth of Gauley river, which empties into the

Kenawha on its right, and from the north east. The whole descent at the falls is near twenty-one feet at low water. The great body of the river is precipitated over the rocks about fifteen feet at a single pitch, and portions of it eighteen or twenty feet, in several places. The river is confined, at this point, between a high mountain on its left, and a range of cliffs on the opposite side. A small triangular shaped piece of bottom land, containing about twenty-five or thirty acres, at Montgomery's ferry, on the left bank of the river, furnishes the only spot adapted to the erection of buildings, for several miles below the falls. It is intersected near the middle by a rivulet from the mountain, immediately in the rear: and a portion of it is liable to inundation. Between the falls and the upper end of this tract, a point of the mountain is interposed, presenting a high and continued mass of rock for several hundred feet, fronting the river, and projecting many yards beyond its base, which has been worn away by the constant action of the current. It would be most advisable to tunnell through this part of the mountain; perhaps it would also be the cheapest plan. In no other way, however, could the requisite quantity of water be safely conveyed to the site below. On the right bank of the river, and for several miles above and below the falls, there is an almost total deficiency of ground for sites. A dam, eight feet high, on the Gauley, three quarters of a mile above its mouth, would raise the water of that river near twenty-three feet above the level of the Kenawha, at the head of the falls: but, in the whole distance between the two points, (two and a quarter miles,) there are not thirty acres of ground that could be occupied.

The nearest site, sufficiently extensive for an armory, is four or five miles below the falls, on the right bank of the river; and the only means of conveying the water to it, which the nature of the intermediate ground will admit, are of the most expensive and insecure kind.

The cliffs which border on the river for several hundred yards below the falls, barely affords room enough at their base, for the passage of a common wagon road, and have no other alternative but that of cutting a tunnel through the rock the whole distance, or resorting to the unsafe expedient of a high river wall, to confine the water. Other difficulties are then to be encountered. The canal would pass a considerable distance through narrow ground, along the margin of the river, composed, for the most part, of a loose aggregation of soil and rocks that have been detached from the hills and cliffs above, and, therefore, might require to be puddled, sometimes to be walled, on the side next the river; besides, several expensive culverts and embankments on the subsequent part of the route.

The vast power at these falls could hardly be more unfavorably circumstanced for the purposes of a national armory, and it is scarcely less objectionable on the score of its position, than of its localities. The bottoms of the Kenawha, that are uncommonly fine and extensive near its mouth, diminish in ascending the river; and five miles from the falls they nearly cease, as before stated. For thirty miles

below, the whole country, it is believed, does not, at this time, furnish subsistence for the population.

The inhabitants of Charleston, and those dependent on the numerous salt work above that place, draw a large portion of their supplies from the lower country, and even from the Ohio river. Provisions are therefore high, and will probably remain so.

The navigation of the Kenawha has been greatly improved by the board of public works of Virginia, and may be considered as constant between Charleston and the Ohio river. It is attended, however, with some inconvenience on account of the descent, which is forty-five feet in about fifty-eight miles; and from the falls to Charleston it is still greater, the distance is thirty-six miles by the course of the river, and the descent sixty-one feet, which must always render the ascending navigation tedious and expensive.

The head waters of the Kenawha pass through several counties of fine land; but, below the junction of Green-briar and New river the country affords no resources whatever for an establishment at the falls. The late civil Engineer of Virginia, in his report to the board of public works in 1820, states, that in thirty-five miles next above Bowyer's ferry "ten acres of good land in a body rarely occurs;" and from Man's creek, a quarter of a mile below Bowyer's ferry, to the mouth of Gauley river, a distance of eighteen miles, that "not a trace of human industry or art is any where to be seen, except a part of a small field which approaches the river, at the mouth of Mill creek. Indeed, for a large portion of that distance, a spot of earth, of sufficient dimensions for the ground plan of a moderate sized dwelling house, is rarely to be seen." This rugged and extraordinary region which prevails between the upper country and the falls, also obstructs the water communication between them. From the junction of Green-briar and New rivers to the falls is sixty-eight miles, and the descent in that distance is seven hundred and twenty-three feet, which is equal to, and probably greater, than the whole descent of the Ohio and Mississippi, from Pittsburg to the Balize.

It is hardly necessary to make any comments on these facts, with the solitary exception of fuel. All supplies of consequence, (perhaps even to the gun stocks) must be procured from a great distance, and a large portion of them by way of the Ohio.

Falls of Coal River.

The lower falls of Coal river are fourteen feet three inches high, and are five miles by water above its junction with the Kenawha, in which distance the descent of the river is said to be fifteen feet. The ordinary rises of the Kenawha vary from fifteen to thirty feet; its extreme rise is stated at forty feet, and is therefore near eleven feet higher than the head of the falls. The ground is advantageously disposed for the erection of water-shops, and all the necessary buildings of an armory;

but nothing certain or satisfactory could be ascertained concerning the quantity of water which the river affords in dry seasons, or the probable period that the power would be interrupted by freshets. At the time it was examined, however, the whole volume of the stream was judged to be insufficient.

The upper falls are about five miles above the lower, and do not exceed eight or ten feet in their whole descent. The quantity of water is also less; two streams discharge into the river between the upper and lower falls, and add about one-third to its volume.

Coal river, at its junction with the Kenawha, is 12 miles below Charleston.

The Little Miami, Paint creek, the Hockhocking, Licking creek, and Little Beaver, are among the most valuable mill streams in the state of Ohio. But, on examination, we were satisfied that neither of them would afford sufficient power during a dry season.

The Little Sandy, in Kentucky, has a fall of eight or nine feet at low water. It is within a mile of the Ohio, and therefore subject to serious interruptions from the backwater of that river, as well as from its own freshets.

The Big Sandy has no fall of any consequence below the Tug Fork.

Not long since there was a considerable fall on the Guyandotte, in Virginia. A broad ledge of rock, extending obliquely across the stream, from the foot of the hills on its left bank, to the opposite shore, made a natural dam eighteen or nineteen feet high, which backed the water for several miles. The fall no longer exists. A grist-mill and considerable part of the adjoining bottom land, were carried away by a freshet. In a few hours the current cleared itself a passage round the rock which terminated abruptly at some yards distance within the bank. The river now flows in its new channel, a few yards to the right, and eighteen feet below the level of its ancient bed.

Mad river affords an abundant supply of water at all seasons, and numerous sites, where it may be employed without interruption. Its distance, however, from useful navigation, and the deficiency of its neighborhood of some articles of primary consequence to a manufactory of arms, are considered as forming decided objections to it. The nearest point of the Ohio river is at Cincinnati, fifty-five miles distant by land, from whence it would be necessary to bring iron and other supplies; and as the country does not contain stone coal, fuel also would be comparatively dear.

The White Water labors under similar disadvantages, and affords no site, it is believed, below its forks at Brookville, in Indiana, that is not liable to interruption from freshets. This stream, however, was not examined.

There are several rapids on the Wabash, below Vincennes, and not far from White River. It is said that a fall of fifteen or twenty feet can be obtained at one of these rapids, near Mount Carmel, by means of a canal from four to six miles in length, and at a moderate expense. As no fact or circumstance then, or since, within our knowledge, would warrant the expectation of obtaining an uninter-

rupted power at that, or at any other point on the Wabash, below Vincennes, as the character and habits of that river, so far as they are known, rendered the contrary almost certain; and, at the same time, created other objections to the occupation of any site upon its banks; and also, as it was well ascertained that the country, in its immediate vicinage, was yet inferior in those resources of most consequence to an armory, we did not perceive a sufficient motive for giving it an examination.

Duncan's Falls, on the Muskingum, are nine miles below Zanesville. The whole descent is 8.75 feet in 2,504 yards, 5.37 feet of which occur in the first 600 yards. The ground below the fall on the right bank of the river, is well adapted to the use of the water power, and affords an extensive and advantageous site. The position for the dam is also favorable. The bed of the river, and both shores, are of rock. But, at the point, where the left wing of the dam would terminate, and thence for 258 yards below it, the hills crowd upon the stream, and would require the erection of a river-wall along their base, to confine the water and convey it to where the ground admits of taking it within the bank. The length of the canal, supposing the works to be placed near Duncan's Run, below the foot of the last rapid, or Deadman's Ripple, would be near 2,000 yards; the average elevation of the ground along its route, is ——feet above the level of low water at the head of the falls, which would therefore be the depth of the excavation; to be diminished or increased, however, by the difference, if any, between the depth of water in the canal and the height of the dam.

It is quite possible, and even probable, that no advantage would be derived from placing the works further down than the foot of the first rapid: from thence to the foot of the last rapid, the descent in the surface of the river, when at its greatest height, or during its rise, may be too inconsiderable to add any thing to the power, or to lessen the period of its interruption; in which case, the whole length of the canal might be reduced to 6 or 800 yards. But, according to the least favorable hypothesis as regards the expense, the dam, river-wall and canal, (admitting the upper part to be made navigable for river craft, and including a lock) would probably cost less than the dam and canal, and water rights, at Zanesville. Four hundred and ninety-four acres of land, with the exclusive privilege of the water, may be purchased for ten thousand dollars, besides two thousand dollars for the probable damage to Mr. Taylor's salt works, on the left bank of the river, above the dam.

The objections to this position arise from the liability of the power to be interrupted by high water. The whole fall is nearly a foot less than at Zanesville, and occurs in a great distance, and that part of it which would probably be made use of, is three feet less. There are considerable obstacles to the current, when the river is high, between the head and foot of the falls at Zanesville, and none immediately below them. There is no similar or apparently equal impediment at Duncan's falls, and the river contracts in its width below the first rapid,

without enlarging proportionately below the last. Hence, it might happen, that the power would frequently cease at Duncan's falls, with a dam eight feet high, while the efficient head of water on the wheels would seldom, if ever, be reduced to its minimum at Zanesville, with a dam only seven feet. Again, the descent tfrom Slagoe's run, to the head of Duncan's falls, is five feet, at low water. A dam eight feet high at the latter place would interfere with the lower water privileges at Zanesville, render the mills at Putnam entirely useless, and destroy the ford across the river at that place. These effects might be attended with other difficulties, besides adding to the cost of the site at Duncan's falls, by the purchase of the water rights, and other property that might be effected at Zanesville and Putnam.

Cheat River.

The greatest fall which can be obtained on this river, within convenient distance of navigation, does not afford a sufficient power at all seasons.

The site of Jackson's mills and iron works, is eight or nine miles from the mouth of the river. The greater portion of these extensive works were stopped during several weeks of the last year, 1823, from want of water. A grist mill with two pairs of four feet stones, and carding machine, alone continued in constant operation. The head of water employed on the wheels is eight feet.

Youghiogheny River, below the Ohiopyle falls.

Several sites were examined between Connellsville and the mouth of this river, including that at the Maria forge, immediately above the town. There is no certainty that the requisite supply of water for an armory could be obtained at any of these points, without damming the river to an inconvenient and dangerous height.

The site at the Maria forge has much the greatest power; the whole fall is sixteen feet at low water. But a part of this fall, it is believed, could not be advantageously employed, and the localities of the site are objectionable on many accounts. At Oliphant's works, six miles below Connellsville, the forge was stopped for two months in 1822; and the supply of water, during that time, was only sufficient to operate two pair of mill stones and a saw mill. The dam was tight, and head of water on the wheels six and seven feet, respectively. These works, therefore, afford a tolerable measure of the quantity of water in the river at that time.

Falls of Tygert Valley Fork.

Those falls are six miles above the junction of the Tygert Valley Fork with the Monongahela, and one hundred miles from Pittsburg. They are estimated to be thirty feet high, and consist of two perpendicular pitches of near fifteen feet each and about one hundred feet apart. From the foot of the lower fall there is a continued rapid for about a mile, in which distance the descent is supposed to exceed twenty feet, making, altogether, fifty or sixty feet fall. The highest rise of the river at the head of the falls is stated to be sixteen feet. The rise below is unknown; but, according to the best information that could be procured, it appears that breast and undershot wheels cannot be employed without interruption from high water. It was also ascertained that the power of the stream, when at its lowest stage, was not more than sufficient to operate four pair of four feet millstones, with a head and fall of twelve feet, and, consequently, the whole fall of thirty feet, employed with reaction wheels, would not afford an adequate power for the armory. The ground is likewise deficient in extent. At no point within a mile and a half below the first fall could the workshops be placed contiguous to each other. In the greater part of this distance the shores of the river consist either of huge masses of detached rock or high precipices, and for eight hundred or one thousand yards, tunnelling and high side walls are the only practicable means that can be employed to convey the water to where it may be taken into a canal; and, after all, suitable ground cannot be obtained for an establishment so extensive as an armory at any point within two miles of the falls.